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SABIN CENTER FOR CLIMATE CHANGE LAW

Inter-American Court of Human Rights

Request for an Advisory Opinion on the Climate Emergency and Human Rights from the Republic of Colombia and the Republic of Chile

Amicus Brief submitted by the Sabin Center for Climate Change Law on Climate Science and Human Rights Obligations

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Statement of Interest

The Sabin Center for Climate Change Law at Columbia Law School submits this *amicus curiae* brief in the matter of the Request for Advisory Opinion submitted by the Republic of Colombia and the Republic of Chile to the Inter-American Court of Human Rights (IACtHR or the Court) regarding the Climate Emergency and Human Rights. The Sabin Center is an academic center dedicated to advancing action on climate change through legal scholarship and engagement. We track developments in global climate change law and litigation, conduct research on the development of legal strategies and legal structures to address climate change, and provide training and educational resources to the legal community. As part of our work, we collaborate with climate scientists as well as a wide range of governmental, non-governmental and academic organizations.

The purpose of this brief is to explain how climate science can help inform the Court's assessment of State obligations to respect, protect, and fulfill human rights in the context of climate change. Our analysis is based on our collective knowledge of climate law, human rights law, and how scientific evidence factors into legal assessments of government obligations to prevent, prepare for, and respond to the effects of climate change.[1]

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[1] *See* MICHAEL BURGER & MARIA ANTONIA TIGRE, GLOBAL CLIMATE LITIGATION REPORT: 2023 STATUS REVIEW (Sabin Center for Climate Change Law, Columbia Law School & United Nations Environment Programme, 2023), https://www.unep.org/resources/report/global-climate-litigation-report-2023-status-review; KATELYN HORNE, MARIA ANTONIA TIGRE, & MICHAEL GERRARD, STATUS REPORT ON PRINCIPLES OF INTERNATIONAL AND HUMAN RIGHTS LAW RELEVANT TO CLIMATE CHANGE (Sabin Center for Climate Change Law, 2023), https://scholarship.law.columbia.edu/faculty_scholarship/3924/; Maria Antonia Tigre, Natalia Urzola, & Alexandra Goodman, *Climate Litigation in Latin America: Is the Region Quietly Leading a Revolution?* 14(1) J. HUM. RTS. & ENVT. 67 (2023), https://www.elgaronline.com/view/journals/jhre/14/1/article-p67.xml; Maria Antonia Tigre, *Climate Change and Indigenous Groups: The Rise of Indigenous Voices in Climate Litigation*, 9(3) E-PUBLICA 214 (2022), https://scholarship.law.columbia.edu/sabin_climate_change/196/; Michael Burger, Jessica Wentz, & Daniel J. Metzger, *Climate Science and Human Rights: Using Attribution Science to Frame Government Mitigation and Adaptation Obligations,* in LITIGATING THE CLIMATE EMERGENCY (César Rodríguez-Garavito, ed. Cambridge University Press 2022), https://www.cambridge.org/core/books/litigating-the-climate-emergency/climate-science-and-human-rights/01D494CAB875536C9FC859D602F34326; Michael Burger, Jessica Wentz, & Radley Horton, *The Law and Science of Climate Change Attribution,* 45(1) COLUM. J. ENVTL. L. 57 (2020), https://journals.library.columbia.edu/index.php/cjel/article/view/4730; Michael Burger & Jessica Wentz, *Climate Change and Human Rights,* in HUMAN RIGHTS AND THE ENVIRONMENT: LEGALITY, INDIVISIBILITY, DIGNITY AND GEOGRAPHY (James R. May and Erin Daly eds., Elgar Encyclopedia of Environmental Law series, Vol. 7, 2019), https://www.e-elgar.com/shop/usd/human-rights-and-the-environment-9781788111454.html; MICHAEL BURGER & JESSICA WENTZ, HUMAN RIGHTS AND CLIMATE CHANGE (United Nations Environment Programme 2015), https://scholarship.law.columbia.edu/sabin_climate_change/119/.

Introduction and Summary

The Court has been asked to provide an advisory opinion "clarifying the scope of State obligations, in their individual and collective dimension, to respond to the climate emergency within the framework of international human rights law, taking into account the differentiated effects that such emergency has on the people of different regions and population groups, nature and human survival on our planet."[2] The Request raises a number of specific questions about State obligations related to climate change mitigation, adaptation, loss and damage, and the protection of vulnerable groups such as children, women, and indigenous peoples.

Underpinning these legal questions are scientific questions about the nature of anthropogenic climate change, its impacts on human and natural systems, and the relative contributions of different State actors to those impacts. For example, as noted in the Request, interpreting the "shared but differentiated responsibilities" of States in relation to climate change requires differentiating the contribution that each State has made to climate change and its impacts.[3] State responsibilities must also be interpreted in light of the need to "avoid, minimize, and address the damages and losses" caused by climate change, and the "need to generate mechanisms and practices that allow for reparation and adaptation at the national, regional, sub-regional and global levels in a fair, equitable and sustainable manner."[4]

This brief provides insights on how climate science can inform the Court's assessment of State obligations to prevent, minimize, provide redress for, or otherwise respond to the harmful effects of climate change. Part I begins with an overview of relevant scientific research, specifically: (i) climate change detection and attribution research, which examines the causal links between human activities, climate change, and effects on people and ecosystems; (ii) projections of future climate change at different warming levels and under different emissions scenarios; and (iii) research on the amount of greenhouse gases (GHGs) that can still be released into the atmosphere without exceeding warming thresholds such as 1.5 or 2°C. Part II explains the connection between scientific evidence of injuries attributable to climate change and threats to specific rights protected

[2] Request for Advisory Opinion on Climate Emergency and Human Rights to the Inter-American Court of Human Rights from the Republic of Colombia and the Republic of Chile (January 9, 2023).

[3] *Id.* at 7.

[4] *Id.*

under the American Convention on Human Rights (American Convention), the Protocol of San Salvador, and other human rights instruments. Part III describes how the science can factor into the Court's assessment and characterization of State obligations related to GHG mitigation, climate change adaptation, climate finance, loss and damage, access to information, public participation, and access to justice.

Key Conclusions: First, there is strong evidentiary support for the finding that climate change poses an "actual" and "imminent" threat to a broad range of human rights. The science shows that climate change is already causing pervasive harm to human and natural systems across the planet, in many cases posing a direct threat to human health, lives, livelihoods, culture, development, self-determination, and the ecosystems and natural resources that humans depend on for all of these values. The severity of the harm will increase with every increment of warming, and many more people and ecosystems will be at risk of severe or catastrophic harm if anthropogenic warming is not limited to 1.5°C or "well below" 2°C.

Second, it is clear that States must achieve deep and rapid reductions in GHG emissions *in the next decade* in order to have a chance of limiting global warming to 1.5°C or "well below" 2°C. Researchers estimate that the remaining carbon budget for a 50% chance of limiting global warming to 1.5°C was only 250 gigatons of carbon dioxide ($GtCO_2$) as of January 2023, equal to approximately six years of current CO_2 emissions.[5] Thus, meeting global climate targets will require ambitious efforts on the part of all States to reduce GHG emissions, with an aim of achieving net zero emissions as quickly as possible, taking into account their respective capabilities and resources. States will need to enact regulations aimed at phasing out fossil fuel use and controlling GHG emissions from other sectors, including emissions attributable to agriculture, livestock, deforestation and other land use decisions. States should seek to reduce emissions of both CO_2 and more potent GHGs such as methane (CH_4), which have a larger effect on near-term warming.

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[5] Piers M. Forster et al., *Indicators of Global Climate Change 202: Annual Update of Large-Scale Indicators of the State of the Climate System and Human Influence,* 15(6) ESSD 2295 (2023), https://essd.copernicus.org/articles/15/2295/2023/; Robin D. Lamboll et al., *Assessing the Size and Uncertainty of Remaining Carbon Budgets,* NAT. CLIM. CHANG. (2023), https://www.nature.com/articles/s41558-023-01848-5.

Third, there are a number of ways in which climate science can be used to characterize the differentiated responsibilities of States with regards to GHG emissions and climate damages. For example, climate attribution research can be used to assess and, in some cases, quantify State contributions to climate change-related harms, which is relevant when assessing the adequacy of State ambition with regards to GHG mitigation, climate finance, and compensation for loss and damage. In addition, research on the equitable allocation of carbon budgets (i.e., "fair share" research) can be used to evaluate the sufficiency of GHG reduction targets, and research on mitigation pathways can be used to evaluate whether a State's climate policies reflect the greatest possible ambition.

Fourth, the science indicates that, even with ambitious GHG mitigation, States will still need to make substantial investments in adaptation to protect human rights from the harmful impacts of climate change. The science also provides critical insights on the ways in which climate change is affecting specific regions, communities, and individuals and the types of adaptation measures that are most urgently needed to protect human rights. This information can be used to evaluate the reasonableness of State adaptation measures.

Finally, it is important to recognize that climate change is a dynamic process and scientific understanding of this process is constantly evolving. States will need to periodically reassess and revise their responses to climate change in light of new scientific evidence. In addition, State obligations related to public participation, access to information, and access to justice should be characterized in a way that will promote science-based decision-making in policy, administrative, and judicial contexts.

I. Overview of Climate Science

Climate science encompasses a range of research aimed at understanding the structure and dynamics of the Earth's climate system and its interactions with other human and natural systems.[6] One key goal of the science is to characterize the mechanisms and consequences of observed climate change. The Intergovernmental Panel on Climate Change (IPCC), the leading scientific authority in this field,[7] has found "unequivocal" evidence that humans are influencing the climate system through GHG emissions and other climate forcers,[8] resulting in "[w]idespread changes in the atmosphere, ocean, cryosphere, and biosphere."[9] Scientists have also amassed a substantial body of evidence on the specific drivers and effects of climate change, including evidence of pervasive harms that are already occurring and will become more severe with additional warming.

This brief focuses on several areas of research that are particularly relevant to the Court's assessment of human rights and State obligations:

- **Detection and attribution science**, which provides insights on the nature and magnitude of anthropogenic climate change and its impacts, as well as the relative contributions of different sources, including State actors, to those impacts.
- **Climate change projections**, which provide insights on the possible future effects of climate change under different warming and emissions trajectories.
- **Carbon budget estimates,** which provide insights on the remaining amount of GHG emissions that can be released into the atmosphere without exceeding warming thresholds such as 1.5 or 2 °C.

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[6] The "climate system" is comprised of the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere, and the interactions between these components.

[7] The IPCC was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) as the leading scientific body for the assessment and synthesis of research on climate change. The IPCC was awarded the Nobel Peace Prize in 2007 for its role in synthesizing and disseminating climate research. The IPCC is widely recognized by courts and other legal authorizes as an authoritative and credible source of climate science, and IPCC findings have been cited in essentially every major legal decision on climate change *See* Maria L. Banda, *Climate Science and the Courts: A Review of U.S. and International Judicial Pronouncements,* ENVIRONMENTAL LAW INSTITUTE (2020), https://www.eli.org/research-report/climate-science-courts-review-us-and-international-judicial-pronouncements; Burger, Wentz, & Horton (2020), *supra* note 1.

[8] A "climate forcer" is any substance that affects the flow of energy coming into or out of the global climate system, thus affecting the amount of heat retained within the system. Anthropogenic climate forcers include GHGs, aerosols, and changes in land use that make land reflect more or less solar energy.

[9] IPCC, CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE SIXTH ASSESSMENT REPORT OF THE IPCC 4 (2021) [hereinafter IPCC AR6 WGI] at 6, 148, https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/.

The sections below include a description of each research area and a summary of key findings from the latest IPCC assessment report (AR6) and other scientific resources.[10]

A. Detection and Attribution of Climate Change

Detection and attribution methods are used to determine whether and to what extent observed changes in the climate and other interconnected systems can be attributed to human influence on climate.[11] In past work,[12] we have identified four interrelated components of attribution research that correspond with different links in the causal chain connecting human activities to climate change impacts: (i) **climate change attribution**, which examines how human activities, in the aggregate, affect the climate system;[13] (ii) **extreme event attribution**, which examines how human-induced changes in the climate system affect the frequency, magnitude, and other characteristics of extreme events;[14] (iii) **impact attribution**, which examines how human-induced changes in the climate system affect other interconnected natural and human systems;[15] and (iv) **source attribution**, which examines the relative contributions of different sectors, activities, and entities to climate change and its impacts.[16]

Attribution studies rely on multiple lines of evidence, including physical understanding of the climate system, observational datasets, paleoclimate reconstructions, statistical methods, and

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[10] This section also briefly discusses research on mitigation and adaptation pathways, which is relevant to the Court's assessment because it provides insights on how States can achieve climate targets. However, an in-depth discussion of that research and its application to the legal questions posed in the Petition is beyond the scope of this brief.

[11] "Detection" refers to the process of demonstrating that a particular variable has changed in a statistically significant way without assigning cause. "Attribution" involves sifting through a range of causative factors to determine the role of one or more drivers with respect to the detected change.

[12] Burger, Wentz & Horton (2020), *supra* note 1.

[13] Climate change attribution, as defined here, would include, e.g., studies examining the relationship between increases in atmospheric concentrations of GHGs and long-term changes in climate variables such as global mean surface temperature, atmospheric water vapor, ocean heat content, and global mean sea level.

[14] Extreme weather is part of the global climate system, and thus extreme event attribution can be viewed as a subset of climate change attribution. However, there are unique challenges associated with extreme event attribution because it deals with climatological extremes and specific events rather than changes in long-term average variables. There is also overlap with impact attribution, as many extreme event studies deal with event characteristics and outcomes that are not purely climatological (e.g., flood damages, wildfire acres burned, or heat wave-related deaths).

[15] Impact attribution would include, e.g., studies aimed at characterizing the effects of climate change on human health, ecosystems, infrastructure, agricultural systems, food security, and water security.

[16] Source attribution includes research aimed at calculating the emissions attributable to specific sources, as well as research that utilizes emissions data to characterize a particular source's contribution to climate change-related trends and impacts, such as sea level rise and increased temperatures.

climate models that can be used to simulate conditions both without and without anthropogenic forcing on climate.[17] Much of the research is quantitative in nature, providing insights on the magnitude of change attributable to human forcing (e.g., increases in average temperature, sea level rise), as well as the extent to which human forcing has influenced the probability or risk of certain extreme events and impacts (e.g., heatwaves, storms, floods). Qualitative research methods are also used, particularly in impact attribution studies that deal with difficult-to-quantify variables.

Detection and attribution research is relevant to discussions about legal responsibility for climate change because it provides insights on both the injuries attributable to climate change and the contribution of specific sources to those injuries. It also provides broader insights on the overall consequences of climate change, the speed at which we are approaching critical targets and tipping points, and the potential consequences should we surpass those targets. This type of information is pertinent when considering State obligations related to GHG mitigation, adaptation, risk disclosure, and loss and damage, among others.

1. Climate Change Attribution

IPCC AR6 found "unequivocal" evidence that human influence has warmed the atmosphere, oceans, and land, primarily through GHG emissions from fossil fuel combustion and other industrial sources.[18] This warming trend is unprecedented in at least the last 2000 years and it is "already affecting every inhabited region across the globe."[19] As of 2019, the decadal average global surface temperature had increased approximately 1.1°C over pre-industrial levels, with larger increases over land (1.59°C) than the ocean (0.88°C).[20] A study using more recent emissions

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[17] The effect of GHG emissions on the atmosphere is an example of anthropogenic "climate forcing" or "radiative forcing", i.e., a change in the energy flux within the Earth's atmosphere. Positive radiative forcing occurs when the Earth receives more incoming energy from sunlight than it radiates into space, and this net gain of energy causes warming. There are a number of natural processes that can affect net radiative forcing – these include changes in the percentage of incoming solar radiation absorbed by the earth, volcanic activity, orbital cycles, and changes in global biochemical cycles (discussed below). There are also other human drivers that can affect atmospheric energy flux – for example, land use changes can have positive or negative effects on radiative forcing, and aerosol emissions have negative radiative forcing and thus contribute to cooling of the climate system. A climate "forcer" is any substance or process that has the potential to affect the energy flux of the atmosphere.

[18] IPCC AR6 WGI at 4.

[19] *Id.*

[20] *Id.* at 5.

data estimated that human-induced surface warming had reached approximately 1.26°C in 2022.[21] Based on these estimates, there is a high probability that humans will cause global warming in excess of 1.5°C within a decade or less.[22] Some of the other consequences of human influence on the climate system include: (i) ocean warming, which is the primary driver of sea level rise and ocean deoxygenation,[23] (ii) ocean acidification, which occurs due to the dissolution of CO_2 in seawater;[24] (iii) substantial declines in sea ice, glaciers, and snowpack;[25] (iv) changes in atmospheric and ocean circulation, which play a major role in regional weather patterns;[26] and (v) changes in the hydrological cycle, with both increases and decreases in precipitation depending on the region.[27]

2. Extreme Event Attribution

As recognized in IPCC AR6, there have been major advances in extreme event attribution over the past decade, and it is now an "established fact" that anthropogenic climate forcing has increased the frequency and/or intensity of some weather and climate extremes, particularly heat extremes.[28] There is also evidence linking human influence to increases in the severity and frequency of heavy precipitation, flooding, droughts, tropical cyclones, and wildfires. Table I.A.2 (next page) summarizes the level of scientific confidence in the attribution of different extremes, based on the IPCC's synthesis of research through 2019.[29]

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[21] Forster et al. (2023), *supra* note 5. This study also looked at decadal averages and estimated that human-induced warming had reached approximately 1.14 °C averaged over the 2013-2022.

[22] *See infra* § I(C) ("Carbon Budgets, Emission Limits, and Fossil Fuel Production Horizons").

[23] The IPCC estimates that ocean warming has accounted for 91% of the total warming in the climate system, and that total ocean heat content increased by 0.396 [0.329 – 0.463 *likely* range] yottajoules between 1971 and 2018. IPCC AR6 WGI at 283, 1214.

[24] IPCC AR6 WGI at 714.

[25] *Id.* at 1215-1216.

[26] *Id.* at 70, 1237.

[27] *Id.* at 1057, 1080-81.

[28] *Id.* at 1517.

[29] *See id.* at 67 (Table TS-2), Chapter 11. The IPCC uses five qualifiers to express level of scientific confidence in findings: very high, high, medium, low, and very low), The following terms are used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, more likely than not >50–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%.

Table I.A.2. Scientific Confidence in Extreme Event Attribution (IPCC AR6)

Type of extreme	Likelihood / confidence in attribution
Extreme heat (including marine heatwaves)	Virtually certain
Extreme precipitation	Likely / high confidence
Extreme precipitation associated with tropical cyclones	Likely / high confidence
Concurrent heatwaves and droughts	Likely / high confidence
Increase in compound flooding	Medium confidence
Increase in agricultural and ecological drought	Medium confidence
Increase in fire weather	Medium confidence
Intensity of tropical cyclones	Medium confidence

Note: These attribution findings reflect the IPCC's assessment of whether human influence on climate is causing an increase in the frequency and/or severity of the extremes listed here, at a global level. The IPCC AR6 WGI report also discusses regional differences in attribution findings for extreme events (*see, e.g.*, Figure SPM.3).

Research on extreme event attribution has continued to advance since 2019, with new studies lending greater confidence to the attribution of wildfires, droughts, tropical cyclones, and other events.[30] The research has revealed a particularly strong link between anthropogenic climate change and increases in the prevalence of wildfire weather and wildfire severity.[31] Researchers have also identified an increasing number of extreme events that would be virtually impossible or extremely unlikely without human influence on the climate system.[32]

[30] *See, e.g.,* Mireia Ginesta et al., *A Methodology for Attributing Severe Extratropical Cyclones to Climate Change Based on Reanalysis Data: The Case Study of Storm Alex 2020*, CLIM. DYN. (2022), https://link.springer.com/article/10.1007/s00382-022-06565-x; Michael Goss et al., *Climate Change is Increasing the Likelihood of Extreme Autumn Wildfire Conditions Across California*, 15 ENVIRO. RES. LETT. 094016 (2020), https://iopscience.iop.org/article/10.1088/1748-9326/ab83a7; G.G. Riberio Neto et al., *Attributing the 2015/2016 Amazon Basin Drought to Anthropogenic Influence*, CLIMATE RESIL. SUSTAIN. (2022), https://rmets.onlinelibrary.wiley.com/doi/10.1002/cli2.25.

[31] *See, e.g.,* Marco Turco et al., *Anthropogenic Climate Change Impacts Exacerbate Summer Forest Fires in California,* 120(25) PROC. NATL. ACAD. SCI. U.S.A. e2213815120 (2023), https://www.pnas.org/doi/full/10.1073/pnas.2213815120 (finding that nearly half of the increase in summer burned forest area in California over the past half-century was attributable to anthropogenic climate change); Zhongwei Liu et al., *The April 2021 Cape Town Wildfire: Has Anthropogenic Climate Change Altered the Likelihood of Extreme Fire Weather?*, 104 BULL. AM. METEOROL. SOC. E298 (2023), https://journals.ametsoc.org/view/journals/bams/104/1/BAMS-D-22-0204.1.xml (finding that climate change had increased the likelihood of wildfire weather like that experienced in the 2021 Cape Town fire by a factor of 1.9).

[32] *See, e.g.,* A. Ciavarella et al., *Prolonged Siberian Heat of 2020 Almost Impossible Without Human Influence,* CLIM. CHANGE (2021), https://link.springer.com/article/10.1007/s10584-021-03052-w.

The latest findings on extreme heat and climate change are particularly alarming. In 2023, numerous global heat records were surpassed by unprecedented margins. The period of June through August was the warmest on record, with an average global surface temperature 1.15°C above the 20th century average of 15.6°C (exceeding the previous record by an astonishing 0.43°C).[33] The record-breaking heat continued in September, with average global surface temperature 1.44°C above the 20th century average (the largest temperature anomaly of *any* month on record).[34] August and September 2023 also set records for the highest monthly sea surface temperature anomalies (both 1.03°C above average) and the lowest global sea ice extent on record.[35]

Many regions experienced record-breaking heatwaves during this period, exacerbated by climate change.[36] South America experienced its highest ever average monthly temperature anomalies for the months of July (2.19°C above average), August (2.40°C above average), and September (2.48°C above average), as well as a prolonged heatwave lasting from July through September with maximum temperatures exceeding 40°C.[37] Attribution researchers have estimated that climate change increased the likelihood of this event by at least 100 times, and that the heatwave would have been 1.4 to 4.3°C cooler in the absence of anthropogenic warming.[38] Extreme sea surface temperatures have also resulted in a mass coral bleaching event with major consequences for Latin American and Caribbean countries.[39] The effects of extreme heat on the region are discussed in further detail below.[40]

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[33] U.S. National Oceanic and Atmospheric Administration (NOAA), *Monthly Global Climate Reports* (2023), *available at* https://www.ncei.noaa.gov/access/monitoring/monthly-report/.

[34] *Id.*

[35] *Id.*

[36] *Extreme Heat in North America, Europe and China in July 2023 Made Much More Likely by Climate Change* (World Weather Attribution, July 25, 2023), https://www.worldweatherattribution.org/extreme-heat-in-north-america-europe-and-china-in-july-2023-made-much-more-likely-by-climate-change/.

[37] NOAA (2023), *supra* note 33.

[38] Sarah Kew et al., *Strong Influence of Climate Change in Uncharacteristic Early Spring Heat in South America* WORLD WEATHER ATTRIBUTION PROJECT (Oct. 10, 2023), https://spiral.imperial.ac.uk/handle/10044/1/106753 (evaluating how climate change influenced 10-day maximum temperatures in the area most affected by the heatwave).

[39] Allison Chinchar, *Coral Bleaching in the Caribbean,* METMATTERS (Royal Metrological Society, September 14, 2023), https://www.rmets.org/metmatters/coral-bleaching-caribbean.

[40] *See infra* Table I.A.3.

3. Impact Attribution

Human-induced climate change is already causing "widespread adverse impacts and related losses and damages" to people and ecosystems across the planet.[41] Observed increases in the severity and frequency of extreme events have been linked to "widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure,"[42] including increases in heat-related human mortality, coral bleaching and mortality, increases in drought-related tree mortality, increases in areas burned by wildfires, and increases in storm-related losses and damages.[43] Slow-onset processes, such as ocean acidification, sea level rise, and changes in average precipitation, are also having pervasive effects on human and natural systems.

The existing body of research leaves no question that climate change poses an enormous risk to human health and well-being. The IPCC estimates that approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change,[44] and there are many interrelated pathways through which climate change adversely affects human lives, physical and mental health, food and water security, livelihoods, property, critical infrastructure (e.g., sanitation, transportation, and energy systems), socioeconomic development, and cultural practices. Some of the key ways in which climate change causes harm include:

- **Ecosystem degradation:** IPCC AR6 expressed *high confidence* that climate change has already caused "substantial damages, and increasingly irreversible losses" in terrestrial, freshwater, and marine ecosystems, including "[w]idespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity."[45] For example, AR6 expressed *very high confidence* that climate change has caused widespread coral bleaching and mortality, primarily due to heat stress associated with ocean warming, resulting in deterioration to and loss of coral reef ecosystems across the planet.[46] Other ecosystems that are uniquely sensitive to and affected by climate change include tropical forests, island ecosystems, coastlines, wetlands, mountains, and polar regions.

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[41] IPCC, CLIMATE CHANGE 2022: IMPACTS, ADAPTATION, AND VULNERABILITY, WORKING GROUP II CONTRIBUTION TO THE SIXTH ASSESSMENT REPORT OF THE IPCC (2022), https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf [hereinafter IPCC AR6 WGII] at 9.

[42] *Id.*

[43] *Id.*

[44] IPCC, *Summary for Policymakers,* CLIMATE CHANGE 2023: SYNTHESIS REPORT, CONTRIBUTION OF WORKING GROUPS I, II, AND III TO THE SIXTH ASSESSMENT REPORT FOR THE IPCC (2023) [hereinafter IPCC AR6 SYR], ¶ A.2.2, https://www.ipcc.ch/report/sixth-assessment-report-cycle/.

[45] *Id.*

[46] IPCC AR6 WGII at § 3.4.2.1.

- **Extreme events:** The increasing severity and frequency of climate and weather extremes is a major source of injury to people and nature. AR6 expressed *very high confidence* that increasing temperatures and heatwaves have increased mortality and morbidity in all regions.[47] Some studies have quantified the increases in heat- and disaster-related mortality attributable to climate change, e.g., Vicedo-Cabrera et al. (2021) examined data from 732 locations in 43 countries and found that 37% (range 20.5-76.3%) of warm season heat-related deaths can be attributed to climate change.[48]

- **Food and water security:** Climate change is already threatening food and water security in many regions, including some of the most vulnerable regions of the world, and these impacts will be much more severe if we surpass 1.5 or 2 °C of warming.[49] For example, IPCC AR6 expressed *high confidence* that climate change has "affected the productivity of all agricultural and fishery sectors, with negative consequences for food security and livelihoods" and, moreover, that it "has contributed to malnutrition in all its forms in many regions… especially for pregnant women, children, low-income households, Indigenous Peoples, minority groups and small-scale producers."[50]

- **Food, water, and vector-borne diseases:** Climate change is affecting the spread of communicable diseases as a result of changes in temperature, humidity, rainfall, sea level rise, and extreme weather. IPCC AR6 expressed *high confidence* that higher temperatures and other climate impacts are already causing an increase in vector-borne diseases, including dengue, Lyme disease, West Nile fever, Rift Valley fever, tick-borne encephalitis, and chikungunya virus, as well as food- and water-borne illnesses.[51]

- **Submergence of low-lying coastal areas and islands:** Coastal areas and islands are increasingly experiencing adverse impacts such as submergence, flooding, erosion, and saltwater intrusion due to sea level rise, more severe storms, and storm surge. These impacts have adverse effects on humans and infrastructure as well as coastal and estuarine ecosystems (which provide critical services to coastal communities). Many people are already facing an imminent threat of forced displacement, and some island states and communities will become uninhabitable due to sea level inundation even if global warming is limited to 2 °C.[52] IPCC AR6 expressed *very high confidence* that small islands and low-

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[47] IPCC AR6 WGII at 51.

[48] A.M. Vicedo-Cabrera et al., *The Burden of Heat-Related Mortality Attributable to Recent Human-Induced Climate Change,* 11 NAT. CLIM. CHANGE 492 (2021), https://pubmed.ncbi.nlm.nih.gov/34221128/.

[49] IPCC AR6 WGII, Ch. 4-5. There are many pathways through which climate change affects food and water systems (e.g., ocean warming, acidification, and deoxygenation adversely affect fisheries; changes in temperature and precipitation can adversely affected agricultural systems; drought and aridity can reduce freshwater availability).

[50] *Id.* at 49, 51.

[51] *Id.* at 51. *See also id.*, Ch. 7.

[52] This is one of the reasons that the UNFCCC Conference of the Parties (COP) revised its objective to limit global warming to "well below 2 °C" or 1.5 °C. However, current pledges under the UNFCCC are not sufficient to meet that objective, and it is likely that many islands and low-lying coastal areas will be inundated due to sea level rise under current emissions trajectories. *See infra* § I.B.

lying cities and settlements will face "severe disruption by 2100, and as early as 2050 in many cases" under *all* climate and socioeconomic scenarios.[53]

- **Humanitarian crises, forced displacement, and migration:** Climate change is "contributing to humanitarian crises where climate hazards interact with high vulnerability."[54] For example, flood and drought-related acute food insecurity and malnutrition have increased in Africa and Central and South America.[55] Climate and weather extremes are also driving displacement in all regions of the world, with Small Island States disproportionately affected.[56] Over 20 million people have been internally displaced annually by weather-related events since 2008, with storms and floods and the most common drivers.[57]
- **Physical and mental health:** Climate change is adversely affecting physical and mental as a result of the hazards described above, including more severe and frequent extreme events, increased exposure to diseases, food and water insecurity, humanitarian conflict, and displacement.[58]

The scientific evidence also demonstrates that the harmful impacts of climate change are disproportionately affecting "the most vulnerable people and systems" and some natural and human systems have already been "pushed beyond their ability to adapt."[59]

Table I.A.3 (next page) summarizes some of the ways in which climate change is specifically affecting Latin America and the Caribbean, based on findings from IPCC AR6 as well as more targeted studies of climate impacts in the region.[60]

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[53] IPCC AR6 WGII at 62.

[54] *Id.* at 11.

[55] *Id.*

[56] *Id.*

[57] *Id.* at 48.

[58] *Id.* at 11.

[59] *Id.*

[60] *See, e.g.,* IPCC AR6 WGII, Ch. 12 ("Central and South America"); Ch. 15 ("Small Islands"); USAID, *Eastern and Southern Caribbean Climate Vulnerability Assessment: 2022 Update* (May 2022), https://www.climatelinks.org/resources/eastern-and-southern-caribbean-climate-vulnerability-assessment; Jerónimo Giorgi & Irene Torres, *Impactos das mudanças climáticas na América Latina e no Caribe*, INTER-AMERICAN INSTITUTE FOR GLOBAL CHANGE RESEARCH (2022), https://latinoamerica21.com/wp-content/uploads/2022/11/PORT_Impactos-das-mudancas-climaticas-na-America-Latina-e-no-Caribe.pdf; Christopher P.O. Reyer et al., *Climate Change Impacts in Latin America and the Caribbean and their Implications for Development,* 17 REG. ENVIRON. CHANGE 1601 (2017), https://link.springer.com/article/10.1007/s10113-015-0854-6; L.J.S. Anjos, & P.M. De Toledo, *Measuring resilience and assessing vulnerability of terrestrial ecosystems to climate change in South America*, 13(30 PLOS ONE 1 (2018), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5858834/; V.R. Barros et al., *Climate change in Argentina: trends, projections, impacts and adaptation*, 6(2) WILEY INTERDISCIP. REV. CLIM. CHANGE 151–169 (2015), https://wires.onlinelibrary.wiley.com/doi/10.1002/wcc.316; Uruguay Ministerio de Ambiente, *Cambio Climático*, https://www.gub.uy/ministerio-ambiente/cambio-climatico; Chile, Ministerio del Medio Ambiente, *Publicaticiones Destacadas*, https://cambioclimatico.mma.gob.cl/publicaciones-destacadas/; México ante el Cambio Climático,

Table I.A.3. Impacts of Climate Change on Latin America and the Caribbean	
Extreme heat	Extreme heat events are becoming increasingly severe and frequent throughout Latin America and the Caribbean, causing harm to people, infrastructure, and ecosystems.[61] The region has experienced a number of record-breaking extreme heat events in recent years, often exacerbating other natural hazards such as drought and glacier melt.[62] In 2023, South America experienced an unprecedented winter heatwave, with temperatures surpassing 35°C in the Andes and 40°C in other areas.[63] The Caribbean basin and Gulf of Mexico also experienced an unprecedented marine heatwave in 2023, with ocean temperatures surpassing 32 °C, which triggered a large-scale bleaching coral bleaching event that was more intense and longer in duration than any event on record.[64]
Extreme precipitation, glacier melt, flooding, and landslides	Extreme precipitation events and glacier loss are contributing to a higher incidence of floods and landslides that pose a risk to human life and infrastructure.[65] Glaciers in the Andes have lost 30% or more of their area since the 1980s, and some glaciers in Peru have lost more than 50% of their area. Extreme precipitation has also increased in many regions, and floods and landslides triggered by heavy rainfall have led to hundreds of fatalities and billions of dollars (USD) in economic losses.[66] Social inequalities, urban expansion, and inadequate city planning increase exposure to these natural hazards.[67]
Coastal hazards	Sea level rise, more severe storms, and compound storm surge pose a risk to coastal residents and communities. It is estimated that 6-8% of the population in Latin America and the Caribbean face high risk associated with sea level rise and coastal hazards.[68] The Caribbean is most impacted: as of 2017, an estimated 22 million people in the Caribbean lived less than six meters above sea level, and the region faces uniquely high exposure to tropical cyclones.[69]

Sistema De Información Sobre El Cambio Climático, https://cambioclimatico.gob.mx; Mexico Programa de Invesigación en Cambio Climático, https://www.pincc.unam.mx/publicaciones/reporte-mexicano/.

[61] IPCC AR6 WGII, Ch. 12, 15; WORLD METEOROLOGICAL ORGANIZATION (WMO), STATE OF THE CLIMATE IN LATIN AMERICA AND THE CARIBBEAN 2021 (2022), https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate/LAC.

[62] Central America, in particular, has been identified as a "hot spot" for high-risk heatwaves. Vikki Thompson et al., *The Most At-Risk Regions in the World for High-Impact Heatwaves*, 14 NATURE COMMUNICATIONS 2152 (2023), https://www.nature.com/articles/s41467-023-37554-1.

[63] *Winter Heat Wave in Chile Offers 'Window" to Warmer World,* REUTERS (August 3, 2023), https://www.reuters.com/world/americas/winter-heat-wave-chile-offers-window-warmer-world-2023-08-03/.

[64] Allison Chinchar, *Coral Bleaching in the Caribbean,* METMATTERS (Royal Metrological Society, September 14, 2023), https://www.rmets.org/metmatters/coral-bleaching-caribbean.

[65] IPCC AR6 WGII at 1691-92.

[66] World Meteorological Organization (WMO), *Climate Change Vicious Cycle Spirals in Latin America and the Caribbean* (July 5, 2023), https://public.wmo.int/en/media/press-release/climate-change-vicious-cycle-spirals-latin-america-and-caribbean. See also José Alex do Nascimento Bento et al., *Impacto das mudanças climáticas sobre o nível de renda na América Latina*, 62(2) REVISTA DE ECONOMIA E SOCIOLOGIA RURAL (2024), https://www.scielo.br/j/resr/a/y8h4LSFSYnjh gt6rWkkkBYn/.

[67] IPCC AR6 WGII at 1714.

[68] *Id.* at 1225.

[69] *Id.* at 2045. In 2017 alone, 22 of 29 Caribbean islands were affected by at least one Category 4 or 5 tropical cyclone. Many of these storms had devastating impacts, e.g., Tropical Cyclone Maria destroyed nearly all of Dominica's infrastructure, with losses amounting to over 225% of the country's annual GDP. *Id.*

Table I.A. Impacts of Climate Change on Latin America and the Caribbean (continued)	
Drought and water scarcity	The frequency and intensity of droughts has increased in South America, Central America, and the Caribbean, primarily due to rainfall deficit.[70] The social and economic consequences of drought are already evident in many contexts, for example, in Central America's so-called "Dry Corridor" in El Salvador, Guatemala, Honduras, and Nicaragua, where there is now a growing dependence on food imports as well as greater food insecurity.[71] The "Central Chile Mega Drought", which has been ongoing since 2010, is the longest drought that the region has seen in at least 1,000 years. The Caribbean faces compound risks to water supply due to a combination of drought, sea level rise, and more severe storms. Glacier retreat is also contributing to water scarcity in glacier-fed water basins.
Agriculture and food production	Extreme temperatures, changes in the timing and magnitude of precipitation, and drought are negatively affecting agricultural systems as well as subsistence farming in some regions., compromising food security.[72] Marine heat waves, ocean acidification, coral reef loss, and other forms of marine ecosystem degradation are also threatening the health and productivity of fisheries in the region, particularly Caribbean fisheries, which are considered to be among the most vulnerable in the world to climate change.[73]
Ocean and coastal ecosystems	Ocean and coastal ecosystems in the region, such as coral reefs, estuaries, salt marshes, mangroves, and sandy beaches, are highly sensitive and negatively impacted by climate change.[74] The loss of coral reef ecosystems, in particular, poses a significant threat to the region.[75] Massive, region-wide decline of corals has been observed across the entire Caribbean basin for decades – e.g., the average stony coral cover on reefs declined by 80% between 1977 and 2001,[76] and marine heatwaves continue to cause widespread declines in tropical corals, kelps, seagrasses, mangroves, and other marine species and other marine habitat forming communities. This important implications for a range of ecosystem services, including food production, carbon storage, and storm protection.[77]
Forest ecosystems	Climate change is causing disruption and damage to forest ecosystems in the region. The Amazon Forest, one of the world's largest biodiversity and carbon repositories, is under severe stress as a result of droughts, higher temperatures, and wildfires, all of which are linked to climate change, as well as land use practices.[78] The southern portion of the Amazon has become a net carbon source, rather than a sink, in the past decade.[79]

[70] IPCC AR6 WGII at 1697, 1736.

[71] *Id.* at 1736.

[72] E.g., the crop growth duration for maize in impacted regions was reduced by at least 5% between 1981-2020 and 2015-2019. IPCC AR6 WGII at 1691.

[73] *Id.* at 2075.

[74] *Id.* at 1691.

[75] FAO, Impacts of Climate Change on Fisheries and Aquaculture, FAO Technical Paper 627 (2018), https://www.fao.org/3/i9705en/i9705en.pdf.

[76] Toby A. Gardner et al., *Long-Term Region-Wide Declines in Caribbean Corals,* 301 SCIENCE 958 (2003), https://www.science.org/doi/10.1126/science.1086050.

[77] Dan A. Smale et al., *Marine heatwaves threaten global biodiversity and the provision of ecosystem services,* 9 NAT. CLIM. CHANGE 306 (2019), https://www.nature.com/articles/s41558-019-0412-1.

[78] IPCC AR6 WGII at 1691.

[79] *Id.* at 1693.

Table I.A. Impacts of Climate Change on Latin America and the Caribbean (continued)	
Infectious diseases	Climate change has significantly increased risks associated with some infectious diseases in the region. For example, the reproduction potential for the transmission of dengue increased between 17% and 80% for the period 1950-1954 to 2016-2021.[80]
Public health	Climate change affects public health through multiple vectors, including extreme weather, infectious diseases, ecosystem degradation, and food and water insecurity.[81] For example, extreme heat is already affecting public health in the region. One meta-analysis focused on South America found that heat-related deaths are increasing across regions[82] and children <1 year are now exposed to 2.35 million more person-days of heatwaves each year, relative to a 1996-2005 baseline.[83] Climate change has also substantially increased human heat stress in the Caribbean,[84] but public health data is more limited for this region.[85]
Wildfires	Exceptionally high temperatures, low humidity, and severe drought have contributed to record-breaking wildfires, causing damage to both ecosystems and human communities.[86]
Migration and displacement	Migration and displacement associated with climatic hazards are becoming more frequent in Latin America and the Caribbean.[87] People living in low-lying coastal areas and islands are at risk of displacement due to sea level rise, coastal submergence, saltwater inundation, and tropical cyclones.[88] Other drivers of displacement and migration include prolonged drought, water scarcity, and food insecurity.[89] Displaced people often face heightened exposure and vulnerability to climate change-related threats.[90] Researchers predict that there will be approximately 17 million internal climate migrants in Latin America by 2050 unless concerted action is taken to reduce GHG emissions, adapt to climate change, and promote more inclusive development.[91]

[80] IPCC AR6 WGII at 1691.

[81] *See, e.g.,* S.C. Bauch et al., *Public Health Impacts of Ecosystem Change in the Brazilian Amazon,* 112(24) PROC. NATL. ACAD. SCI. 7414 (2015), https://www.pnas.org/doi/full/10.1073/pnas.1406495111.

[82] Stella M. Hartinger et al., *The 2022 South America Report of the Lancet Countdown on Health and Climate Change,* 20 LANCET REGIONAL HEALTH – AMERICAS (2023), https://www.thelancet.com/journals/lanam/article/PIIS2667-193X(23)00044-3/fulltext at 2.

[83] *Id.*

[84] Claudia Di Napoli et al., *Heat Stress in the Caribbean: Climatology, Drivers, and Trends of Human Biometeorology Indices,* 43(1) INT. J. CLIMATOL. 405 (2023), https://rmets.onlinelibrary.wiley.com/ doi/full/10.1002/joc.7774; Marisol Yglesias-González et al., *Code Red for Health response in Latin America and the Caribbean: Enhancing People's Health Through Climate Action*, 11 LANCET REGIONAL HEALTH – AMERICAS 100248 (2022), https://www.thelancet.com/journals/lanam/article/PIIS2667-193X(22)00065-5/fulltext.

[85] *See* Nina Rise, *Climate Change and Health in the Caribbean: A Review Highlighting Research Gaps and Priorities,* 8 J. CLIM. CHANGE HEALTH 100126 (2022), https://www.sciencedirect.com/science/article/pii/S2667278222000153.

[86] WMO (2023), *supra* note 66.

[87] IPCC AR6 WGII at 1767-68.

[88] E.g., Puerto Rico experienced a 14% population decline in 2 years following Hurricane Maria (2017) and the entire population of Ragged Island in the Bahamas was forcibly displaced by Hurricane Irma (2017). *Id.* at 1084, 2069-70.

[89] IPCC AR6 WGII at 1768.

[90] *See, e.g.,* Adelle Thomas & Lisa Benjamin, *Climate Justice and Loss and Damage: Hurricane Dorian, Haitians and Human Rights,* GEOGRAPHICAL J. (2022), https://rgs-ibg.onlinelibrary.wiley.com/doi/abs/10.1111/geoj.12484.

[91] KANTA KUMARI RIGAUD ET AL., GROUNDSWELL: PREPARING FOR INTERNAL CLIMATE MIGRATION (World Bank 2018), https://openknowledge.worldbank.org/handle/10986/29461.

4. Source Attribution

Although most attribution studies deal with the aggregate effect of human activities on the climate system, researchers are now using source attribution data to isolate the contribution of specific entities to changes in the climate system, extreme events, and impacts. In some cases, it is even possible to isolate the effects of GHG emissions on a per-ton basis.[92] Some of the research focuses on state-level contributions to climate change-related harms. For example, Otto et al. (2017) demonstrated that it is possible to quantify the proportional contribution of individual countries to specific extreme events, using the example of the Argentinian heatwave of 2013-14.[93] An earlier attribution study had found that anthropogenic climate change had made the heatwave approximately five times more likely to occur.[94] Using climate models, Otto et al. determined that emissions from the U.S. and EU had increased the likelihood of that event by 28% and 37%, respectively.[95] The same technique can be applied to other events, for example, a 2022 heatwave in Argentina and Paraguay, which scientists estimate was *60 times more likely to occur* due to anthropogenic climate change, and the 2023 South American heatwave, which scientists estimate was at least *100 times more likely to occur* due to anthropogenic climate change.[96]

Researchers have also developed techniques for estimating economic damages attributable to state-level emissions. For example, Callahan & Mankin (2022) used historical emissions data and climate models to quantify each country's responsibility for historical temperature-driven income changes in all other countries.[97] They found that the top five emitters (U.S., China, Russia, Brazil,

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[92] E.g., there is a near-linear relationship between cumulative CO_2 emissions and observed declines in September sea ice (the month when Arctic sea ice typically reaches its minimum extent). Based on this, researchers have estimated that each metric ton of CO_2 that is released into the atmosphere may result in a sustained loss of 3 ± 0.3 square meters of September sea ice in the Arctic. Dirk Notz & Julienne Stroeve, *Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission*, 354 SCIENCE 747 (2016), https://www.science.org/doi/10.1126/science.aag2345.

[93] Friederike Otto et al., *Assigning Historic Responsibility for Extreme Weather Events*, 7 NAT. CLIM. CHANGE 757 (2017), https://www.nature.com/articles/nclimate3419.

[94] A. Hannart et al., *Causal Influence of Anthropogenic Forcings on the Argentinian Heat Wave of December 2013*, 96(12) BULL. AM. METEROL. SOC. S41, https://journals.ametsoc.org/view/journals/bams/96/12/bams-d-15-00137.1.xml.

[95] Otto et al. (2017), *supra* note 93.

[96] Kew et al. (2023), *supra* note 38; Juan Antonio Rivera et al., *Climate Change Made Record Breaking Early Season Heat in Argentina and Paraguay About 60 Times More Likely* (World Weather Attribution Project, Dec. 21, 2022), https://www.worldweatherattribution.org/wp-content/uploads/WWA-Argentina-Scientific-report.pdf.

[97] C.W. Callahan & J.S. Mankin, *National Attribution of Historical Climate Damages,* 172 CLIM. CHANGE 40 (2022), https://link.springer.com/article/10.1007/s10584-022-03387-y.

and India) had collectively caused US$6 trillion in income losses from warming since 1990, and that many other countries are responsible for billions in losses. The study also found that the distribution of warming impacts from emitters is highly unequal, with high-income, high-emitting countries actually accruing economic benefits while low-income, low-emitting countries are experiencing severe economic losses as a result of climate change.

While these studies highlight how far attribution research can go in terms of quantifying state-level contributions to climate impacts, it is also possible to draw inferences about state responsibility for climate impacts based on the State's relative contribution to global emissions. There are a number of different ways to account for state emissions, all of which provide complementary insights on the nature of State contributions to and responsibility for climate change. These include: (i) historical, present, and future emissions; (ii) territorial, consumption-based, and extraction-based emissions;[98] and (iii) total emissions, per capita emissions, and various metrics of emissions intensity. Climate science does not dictate which of these accounting methods should prevail, but source attribution research provides the underlying emissions data.

B. Projections of Future Climate Change

Climate change projections provide insights on the magnitude and scope of changes and impacts that may occur under different emission trajectories and warming scenarios. Like attribution research, climate projections are based on physical understanding, climate datasets, statistical methods, and climate models. Such projections are relevant when assessing the foreseeability of future climate harms and corresponding legal obligations to control GHG emissions and prepare for the effects of climate change.

There is no question that the effects of climate change will become increasingly severe and pervasive as GHGs continue to accumulate in the atmosphere. However, the relationship between emissions, changes in the global climate system, and corresponding impacts is not always linear – for example, there are potential tipping points, feedback cycles, and cascading impacts that could

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[98] Territorial emissions are generated from combustion, industrial processes, and land use changes within a State's borders. Consumption-based emissions are the emissions embodied in the products consumed within a state. Extraction-based emissions are the emissions embodied in the fossil fuels produced within a State. *See* PETER ERICKSON & MICHAEL LAZARUS, ACCOUNTING FOR GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE SUPPLY OF FOSSIL FUELS (Stockholm Environment Institute 2013), https://www.sei.org/publications/accounting-for-greenhouse-gas-emissions-associated-with-the-supply-of-fossil-fuels/.

result in acceleration of certain trends such as sea level rise. Even with these complexities, the IPCC has stated that global climate models can provide credible quantitative estimates of future climate change for most variables at large geographic scales.[99]

IPCC AR6 found that "global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered", and that "global warming of 1.5°C and 2°C will be exceeded during the 21st century" unless there are deep reductions in GHG emissions in the next few decades.[100] In the near term, global warming is *more likely than not* to reach 1.5°C even under a very low GHG emission scenario (SSP1-1.9), and this level of warming will cause "unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans (*very high confidence*)."[101]

The science indicates that the loss and damage caused by anthropogenic climate change will be severe for some regions and communities even if humans limit global warming to 1.5 or 2.0°C, and significantly worse if we exceed those thresholds (see Table 1.B, next page).[102] The effects of climate change will also interact with non-climatic risks, creating "compound and cascading risks that are more complex and difficult to manage."[103] IPCC AR6 expressed *very high confidence* that "[n]ear-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all."[104]

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[99] IPCC AR6 WGI, Ch. 4.

[100] IPCC AR6 WGI at 14.

[101] IPCC AR6 WGII at 13.

[102] IPCC, GLOBAL WARMING OF 1.5°C. AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5°C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS 5 (2018), https://www.ipcc.ch/sr15/ [hereinafter IPCC 1.5°C REPORT].

[103] *Id.*

[104] IPCC AR6 WGII SPM, ¶ B3.

Table I.B. Select Impacts of Climate Change at Different Levels of Warming (AR6)[105]

Projected Impacts	Global Temperature Increase			
	1.5°	2.0°	3.0°	4.0°
Water availability and water-related hazards. Risks in physical water availability and water-related hazards will continue to increase by the mid- to long-term in all assessed regions, with greater risk at higher global warming levels (*high confidence*).				
People in urban areas exposed to water scarcity from severe droughts	+ 350 million	+ 410 million		
Projected decline in snowmelt water availability for irrigation in some snowmelt dependent river basins		20% decline		40 % decline
Adaptation limits for islands and glacier/snowmelt dependent regions	>1.5°C, limited freshwater resources pose potential hard limits for small islands and regions dependent on glacier and snow-melt.			
Projected increases in direct flood damages, without adaptation		↑ 1.4 - 2x compared to 1.5°C	↑ 2.5 - 3.9x compared to 1.5°C	
Food Production and Access. Climate change will increasingly put pressure on food production and access, especially in vulnerable regions, undermining food security and nutrition (*high confidence*).				
Risk of food insecurity in vulnerable regions	Moderate risk	High risk	Risk "expands substantially" compared with 2°C	
Biodiversity. Biodiversity loss and degradation, damages to and transformation of ecosystems are already key risks for every region due to past global warming and will continue to escalate with every increment of global warming (*very high confidence*). Risks to ecosystem integrity, functioning and resilience are projected to escalate with every tenth of a degree increase in global warming (*very high confidence*).				
Percent of assessed species in terrestrial ecosystems likely facing a "very high risk" of extinction	3-14%	3-18%	3- 29%	3-39%
Risk of biodiversity loss in ocean and coastal ecosystems	moderate - very high risk	moderate – very high risk	high - very high risk	
Loss of warm-water coral reefs	70-90% decline	>99% decline		
Biodiversity hotspots	24% of species face "very high extinction risk"			
Polar, mountain, and coastal ecosystems	>1.5°C, irreversible impacts on some ecosystems, particularly those impacted by ice-sheet melt, glacier melt, and sea level rise.			

Some impacts and hazards do not scale linearly with emissions and are highly sensitive to even minor increases in temperature. For example, even "relatively small incremental increases in global warming (+0.5°C) cause statistically significant changes in extremes" including

105 These impacts were selected based on the availability of information about the magnitude of the impact at specific warming levels in IPCC AR6 WGII. This is not intended to be an exhaustive or comprehensive list of climate impacts.

temperature extremes (*high confidence*), precipitation extremes (*high confidence*), tropical cyclones (*medium confidence*), and the worsening of droughts in some regions (*medium confidence*).[106] The IPCC also predicts that sea level rise will exponentially increase flooding risk in some regions, including the Caribbean.[107] Ecosystem impacts are another example of a non-linear hazard: climate change causes cascading and compounding disruptions to ecosystems, such that small increases in warming can have major impacts on ecological health and biodiversity, which may in turn have significant impacts on human rights.

A recent study on the human costs of global warming found that current climate policies, which are projected to result in 2.7°C of warming by end-of-century (2080-2100), would leave up to one third (22-39%) of people outside of the "human climate niche", i.e., the climatic conditions in which most humans have historically survived, and would expose approximately 22% of people to extreme heat (≥ 29°C).[108] In comparison, limiting global warming to 1.5°C would reduce the number of people outside of the climate niche by approximately half, and only 5% of people would be exposed to extreme heat.[109] The study also looked at country-level exposure to extreme heat, as well as how country-level per capita GHG emissions increased population exposure to extreme heat, thus providing insights on State responsibility and State injury under different warming scenarios. This analysis provides further evidence of the inequity inherent in climate change: whereas countries in the global north are responsible for most climate forcing, the vast majority of projected exposure to extreme heat under a 2.7°C scenario will occur in the Global South, including Latin America and the Caribbean (see Figure I.B, next page).

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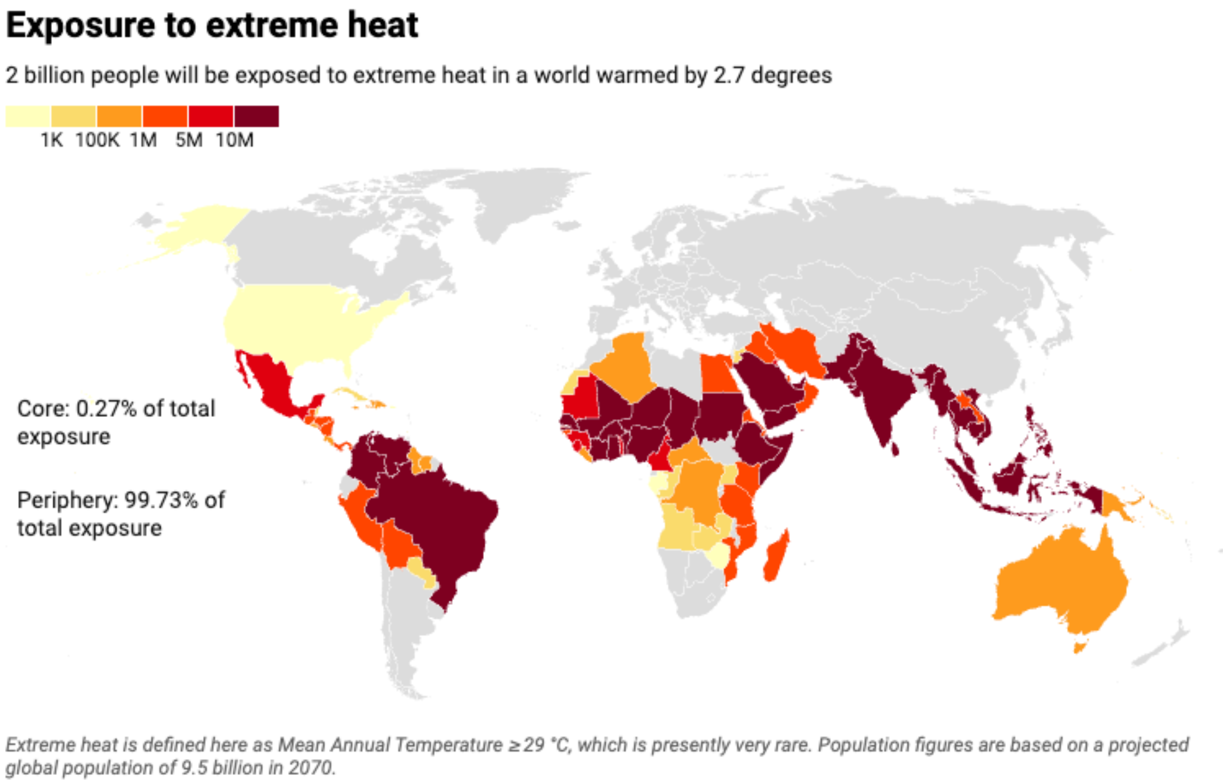
[106] IPCC AR6 WGI at 1517.

[107] IPCC AR6 WGII, Ch. 15 ("Small Islands").

[108] Timothy M. Lenton et al., *Quantifying the Human Cost of Global Warming,* NAT. SUSTAIN. (2023), https://www.nature.com/articles/s41893-023-01132-6.

[109] *Id.*

Figure 1.B: Projected Exposure to Extreme Heat at 2.7°C



Source: Lenton et al. (2023)

Adaptation measures can play a significant role in mitigating certain risks, such as the risks associated with extreme precipitation and flooding. However, adaptation may not be as effective at mitigating other harmful impacts, such as those on biodiversity and ecosystems. Moreover, the effect of climate change on vulnerable populations and ecosystems often reduces their adaptive capacity, thus creating a compounding problem where adaptation becomes increasingly challenging and costly as climate change becomes more severe. Additionally, most adaptations involve tradeoffs, and there are risks of maladaptation and inequitable adaptation.

The impacts of climate change may also become significantly worse if and when the world surpasses certain "tipping points", i.e., thresholds that, when exceeded, will result in large and typically irreversible changes in the climate and connected systems. [110] Key examples of important tipping points within the climate system are the melting of the Greenland ice sheet (an essentially

[110] The IPCC defines a tipping point as a "critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly". IPCC AR6 WG1 at 95.

irreversible process that would ultimately trigger meters of sea level rise as well as changes in atmospheric and ocean dynamics), the melting of Arctic winter sea ice, the dieback of the Amazon rainforest, the loss of mountain glaciers, and the collapse of boreal permafrost. Some critical tipping point thresholds may have already been surpassed, although the full effects have not yet manifested due to time lags and/or incomplete understanding.[111] This highlights an important aspect of tipping points: surpassing thresholds can be "locked in" before the actual event occurs (e.g., the melting of the Greenland ice sheet may already be inevitable due to existing warming).[112] Although much is unknown about the timing and potential consequences of climate tipping points, there are significant risks associated with surpassing these thresholds, since consequences can be so large.[113]

C. Carbon Budgets, Emission Limits, and Fossil Fuel Production Horizons

Global GHG budgets define the maximum amount of GHGs that can be released into the atmosphere while still limiting global warming to pre-defined targets, such as 1.5°C or 2.0°C. Most of the research in this area deals with the global carbon budget, since CO_2 is the dominant source of anthropogenic warming and much is known about CO_2 emissions. Researchers have developed and are continuously updating estimates of the remaining global carbon budget based on assessments of carbon cycle sources and sinks on a global level, including estimates of anthropogenic emissions and land use changes.

Estimating carbon or GHG budgets involves several steps: (i) estimating the total amount of CO_2 and/or other GHGs that can be released into the atmosphere while limiting global warming to a specific temperature target, (ii) determining how much of the budget has already been utilized by historical emissions, and (iii) calculating the remaining share of the carbon budget for subsequent years (and how that budget may be allocated across those years). The global carbon

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[111] David Armstrong McKay et al., *Exceeding 1.5° Global Warming Could Trigger Multiple Climate Tipping Points*, 377(6611) SCIENCE eabn7950 (2022), https://www.science.org/doi/10.1126/science.abn7950.

[112] Niklas Boers & Martin Rypdal, *Critical Slowing Down Suggests that the Western Greenland Ice Sheet is Close to a Tipping Point,* 118(21) PROC. NATL. ACAD. SCI. e2024192118 (2021), https://www.pnas.org/doi/10.1073/pnas.2024192118 (finding that the Greenland Ice Sheet melt tipping point is between 0.8°C and 3.2°C of warming above pre-industrial levels).

[113] Timothy M. Lenton et al., *Climate Tipping Points – Too Risky to Bet Against,* 575(7784) NATURE 592 (2019), https://www.nature.com/articles/d41586-019-03595-0.

budget is typically expressed in terms of a range of gigatons of CO_2 that can be emitted at a specified probability (e.g., 67%) of remaining within a temperature target.

IPCC AR6 synthesized research on the remaining carbon budget, and found that we would need to limit global CO_2 emissions to 400 billion tons from the start of 2020 in order to have a 67% probability of remaining within 1.5°C of warming, and 1150 billion tons in order to have a 67% probability of limiting warming to 2°C.[114] More recent assessments have found that the remaining carbon budget for 1.5°C had shrunk to 250 billion tons of CO_2 as of January 2023 based on emissions data through 2022.[115] At the current rate of emissions, the world will exhaust the remaining 1.5°C carbon budget before the end of 2030 (and possibly within the first half of the 2020s). The World Meteorological Organization (WMO) estimates that there is a 66% likelihood that annual average global surface temperature will be more than 1.5°C above preindustrial levels for at least one year between 2023 and 2027.[116] Monthly average global temperature temporarily exceeded the 1.5°C threshold in July 2023, which was the hottest month on record.[117]

Estimates of the remaining CO_2 budget are based on assumptions about historical and future emissions of non-CO_2 forcers, such as methane (CH_4), nitrous oxide (N_2O), and various short-lived climate forcers. The assumed future emissions of non-CO_2 emissions can be thought of as "budgets" as well, since any emissions in excess of those assumptions will result in additional warming.[118] Conversely, if countries are able to achieve more rapid reductions in non-CO_2 forcers, this would allow for a larger CO_2 budget. Most non-CO_2 forcers are also much more potent than CO_2 and reducing these highly potent GHGs can help limit near term warming.[119]

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[114] IPCC WGI at 29. See also IPCC AR6 WGIII at 6-7.

[115] Forster et al. (2023), *supra* note 5; Lamboll et al., (2023), *supra* note 5.

[116] WMO, GLOBAL ANNUAL TO DECADAL CLIMATE UPDATE, TARGET YEARS: 2023-2027 (May 2023), https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years.

[117] ECMWF, *July 2023 Sees Multiple Global Temperature Records Broken*, https://climate.copernicus.eu/july-2023-sees-multiple-global-temperature-records-broken (multiple temperature records were broken in July 2023 – for example, the 29 days from July 3-31 were the hottest 29 days in the global temperature record).

[118] *See, e.g.,* Global Carbon Project, https://www.globalcarbonproject.org; Marielle Saunois et al., *The Global Methane Budget 2000-2017*, 12(3) EARTH SYST. SCI. DATA 1561 (2020), https://essd.copernicus.org/articles/12/1561/2020/; CSIRO, *Global Methane Budget*, https://www.csiro.au/en/research/environmental-impacts/emissions/global-greenhouse-gas-budgets/global-methane-budget. IPCC AR6 WGI, Ch. 5 ("Global Carbon and Other Biogeochemical Cycles and Feedbacks"); Ch. 6 ("Short-Lived Climate Forcers").

[119] For example, methane (CH_4) is 84 times more potent than CO_2 when measured on a 20-year timespan, and its atmospheric lifetime is approximately 12 years, whereas the atmospheric lifetime of CO_2 is 300-1,000 years.

IPCC AR6 also examines emission trajectories and reduction pathways in reference to temperature targets and carbon budgets. Key findings are that:

- Models suggest that existing policies, as of 2019, would lead to global warming of 3.2 [2.2-3.5] °C.[120] Existing policies could result in warming at or above 4°C if climate sensitivity[121] or carbon cycle feedbacks are larger than the best estimate.[122]
- Deep, rapid and sustained GHG emissions reductions, reaching net zero CO_2 emissions and including strong emissions reductions of other GHGs, in particular CH4, are necessary to limit warming to 1.5°C (>50%) or less than 2°C (>67%) by the end of century (*high confidence*).[123] Emission reductions must include deep reductions in energy system CO_2 and GHG emissions (*high confidence*), which will in turn require the rapid phase out of fossil fuels and increased production from low- and zero-emitting sources.[124]
- Projected cumulative CO_2 emissions over the lifetime of existing fossil fuel infrastructure are expected to exceed the total cumulative net CO_2 emissions for limiting warming to 1.5°C, and are approximately equal to the total cumulative net CO_2 emissions for limiting warming to 2°C with a likelihood of 83%."[125] This means that there will inevitably be stranded fossil fuel assets if warming is limited to 2°C.[126]
- Approximately 80% of coal, 50% of gas, and 30% of oil reserves must remain unused if warming is to be limited to 2°C, and significantly more reserves must remain unused if warming is to be limited to 1.5°C.[127] These figures could change through additional abatement – for example, the installation of carbon capture systems at power plants and industrial facilities – but current deployment of such systems is extremely limited.

The IPCC analysis is supplemented by the United Nations Environment Programme (UNEP) "Production Gap" reports, which examine the discrepancy between planned fossil fuel production and global production levels consistent with limiting warming to 1.5 or 2°C. The 2021 report found

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[120] IPCC AR6 SYR at 57. A more recent assessment estimates that climate policies as of 2022 would likely result in 2.7°C [2.2-3.4°C] of warming. Climate Action Tracker, *Warming Projections Global Update: November 2022* (Climate Analytics & New Climate Institute, 2022), https://climateactiontracker.org/documents/1094/CAT_2022-11-10_GlobalUpdate_COP27.pdf.

[121] "Climate sensitivity" refers to the sensitivity of the climate system to radiative forcing, e.g., how much warming will occur in response in response to a doubling of atmospheric CO_2 concentrations.

[122] IPCC AR6 SYR at 57.

[123] *Id.*

[124] IPCC AR6 WGIII at 89.

[125] IPCC AR6 SYR at 58.

[126] IPCC AR6 WGIII at 698.

[127] *Id.*

that fossil fuel producers are planning to extract more than double the amount of oil, gas, and coal by 2030 than is consistent with limiting warming to 1.5°C.[128]

There is also research on the equitable allocation of the global carbon budget among different countries and sectors, consistent with the UNFCCC discussions on State's "common but differentiated" responsibilities and "fair share" obligations.[129] This area of research implicates physical climate science, but it also deals with ethical and normative questions – for example, how to account for historical emissions, population, development status, and other differences between countries when assigning responsibility for future emission reductions. The research identifies specific indicators or metrics that are relevant when assessing national fair shares (e.g., per capita emissions) and demonstrates how those indicators can be factored into quantitative assessments of GHG targets. The resulting estimates of "fair share obligations" depend on the weight assigned to these different metrics and the specific circumstances of the country being assessed.

D. Mitigation and Adaptation Pathways

As the global carbon budget for 1.5 and 2°C is rapidly shrinking, it is clear that governments and other decision-makers will need to pursue ambitious GHG reduction measures as well as adaptation programs to protect people from the harmful effects of climate change. There is a growing body of research on mitigation and adaptation pathways, some of which is summarized in IPCC reports. Some examples include: technical research on the efficacy, cost, availability, and feasibility of specific GHG reduction technologies for specific sectors and sources;[130] pathways to economy-wide decarbonization;[131] and research on adaptation options for many different types of

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[128] UNEP, 2021 PRODUCTION GAP REPORT, https://www.unep.org/resources/report/production-gap-report-2021.

[129] *See, e.g.,* K.W. Steininger et al., *Sectoral carbon budgets as an evaluation framework for the built environment*, 1(1) BUILDINGS AND CITIES 337 (2020); Kaylin Lee et al. *Fair distributions of carbon dioxide removal obligations and implications for effective national net-zero targets*, 16 ENVIRON. RES. LETT. 094001 (2021); Jan S. Fuglestvedt & Steffen Kallbekken, *Climate Responsibility: Fair Shares?* 6 NAT. CLIM. CHANGE 19 (2016); Lavanya Rajamani et al., *National 'fair shares' in reducing greenhouse gas emissions within the principled framework of international environmental law*, 21(8) CLIM. POLICY 983 (2021); Jason Hickel, *Quantifying National Responsibility for Climate Breakdown: An Equality-Based Attribution Approach for Carbon Dioxide Emissions in Excess of the Planetary Boundary,* 4(9) LANCET PLANETARY HEALTH E399 (2020).

[130] See, e.g., João Carlos de Moraes Sá et al., *Low-carbon agriculture in South America to mitigate global climate change and advance food security,* 98 ENVIRON. INT. 102 (2017), https://www.sciencedirect.com/science/article/abs/pii/S0160412016306341.

[131] See, e.g., *Deep Decarbonization Pathways*, https://ddpinitiative.org; Christopher Bataille et al., *Net-zero Deep Decarbonization Pathways in Latin America: Challenges and Opportunities* (Inter-American Development Bank Sept. 2020), *Deep Decarbonization Pathways in Latin America and the Caribbean (DDP-LAC) – An Assessment of*

climate impacts.[132] Although this research is not the focus of our brief, it is still relevant to discussions about state responsibilities related to climate change as it provides insights on the viability of different options for achieving net zero emissions and adapting to climate change.

Low-Emission Development Strategies in Six LAC Countries, Special Edition: Energy Strategy Reviews (2020-2021), https://publications.iadb.org/en/net-zero-deep-decarbonization-pathways-latin-america-challenges-and-opportunities; CACIA PIMENTEL & MARIA JOAO ROLIM, CAMINHOS JURIDÍCOS E REGULATÓRIOS PARA A DESCARBONIZAÇÃO NO BRASIL (2021).

[132] *See, e.g.*, Celia Harvey et al., *Climate Change Impacts and Adaptation Among Smallholder Farmers in Central America,* 7 AGRIC. FOOD. SECUR. 57 (2018), https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/s40066-018-0209-x.

II. The Effect of Climate Change on Human Rights

The Request seeks additional clarification on "the grounds for, and the scope of, human rights affected by the climate emergency."[133] Many human rights bodies, tribunals, and courts, including this Court, have recognized that climate change poses a threat to fundamental rights, such as the rights to life, health, food, water, housing, privacy and family life, culture, development, and a clean and healthy environment.[134] There is clear scientific support for this determination: existing research indicates that climate change threatens the effective enjoyment of a broad array of human rights, and that this threat is both "actual" and "imminent" in light of attributed climate impacts and projections of future climate change. The science also shows that climate change is disproportionately affecting certain groups and individuals, including groups that are owed special protection under human rights law.

A. Climate change threatens a broad array of human rights

As described in Part I, the scientific evidence shows that climate change is already having pervasive and harmful impacts on human and natural systems across the planet, and these impacts

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[133] Request for Advisory Opinion at 6.

[134] *See, e.g.,* Inter-American Court of Human Rights, Advisory Opinion OC-23/17 (Nov. 15, 2017), https://www.corteidh.or.cr/docs/opiniones/seriea_23_ing.pdf; UN Human Rights Council, Res. A/HRC/RES/50/9 (July 14, 2022), https://www.ohchr.org/en/climate-change/human-rights-council-resolutions-human-rights-and-climate-change; UN General Assembly, *The Human Right to a Clean, Healthy and Sustainable Environment,* A/RES/76/300 (July 28, 2022), https://digitallibrary.un.org/record/3983329; Inter-American Commission of Human Rights (IACHR), Resolution 3/2021, *Climate Emergency: Scope of Inter-American Human Rights Obligations* (2021), https://www.oas.org/en/iachr/decisions/pdf/2021/resolucion_3-21_ENG.pdf; UN Human Rights Committee, *Billy et al. v. Australia*, Communication No. 3624/2019, Doc. No. CCPR/C/135/D/3624/2019 (Sept. 22, 2022, https://ccprcentre.org/files/decisions/CCPR_C_135_D_3624_2019_34335_E.pdf; *Urgenda Foundation v. The State of The Netherlands* [2019] ECLI:NL:HR:2019:2006, https://climatecasechart.com/non-us-case/urgenda-foundation-v-kingdom-of-the-netherlands/; *Future Generations v. Ministry of the Environment and Others*, Corte Suprema de Justicia [C.S.J.] [Supreme Court], abril 5, 2018, M.P: L. Villabona, Expediente : 11001-22-03-000-2018-00319-01 (Colomb.), https://climatecasechart.com/non-us-case/future-generation-v-ministry-environment-others/; *Neubauer, et al. v. Germany,* Bundesverfassungsgericht [BVerfG] [Federal Constitutional Court], Mar. 24, 2021, Case No. BvR 2656/18/1, BvR 78/20/1, BvR 96/20/1, BvR 288/20, https://climatecasechart.com/non-us-case/neubauer-et-al-v-germany/; *Leghari v. Pakistan*, (2015) W.P. No. 25501/201, https://climatecasechart.com/non-us-case/ashgar-leghari-v-federation-of-pakistan/; UN Committee on the Rights of the Child, *Sacchi v. Argentina*, Communication No. 107/2019, Doc. No. CRC/C/88/D/104/2019 (Oct. 8, 2021), https://climatecasechart.com/non-us-case/sacchi-et-al-v-argentina-et-al/ (although Sacchi v. Argentina was dismissed for failure to exhaust remedies, the tribunal acknowledged the threat that climate change posed to petitioners' human rights); Brussels Court of First Instance, *VZW Klimaatzaak v. Kingdom of Belgium & Others*, 17 November 2021, https://climatecasechart.com/non-us-case/vzw-klimaatzaak-v-kingdom-of-belgium-et-al/; Municipal Court in Prague, *Klimatická žaloba ČR v. Czech Republic*, Judgment No. 14A 101/2021, 15 June 2022, https://climatecasechart.com/non-us-case/klimaticka-zaloba-cr-v-czech-republic/; Federal Supreme Court of Brazil, *PSB et al. v. Brazil (on Climate Fund)*, ADPF 708, 1 July 2022, https://climatecasechart.com/non-us-case/psb-et-al-v-federal-union/.

will become increasingly severe with each additional increment of warming.[135] Some of the most prevalent sources of injury include more frequent and severe extreme events, resulting in greater exposure to conditions that endanger lives, livelihoods, health, property, infrastructure, cultural practices, and community cohesion; food and water insecurity; the submergence of low-lying coastal areas and islands; pervasive impacts on ecosystems and disruption of critical ecosystem services; forced displacement due to sea level rise, natural hazards, and other climate drivers; impaired physical and mental health; and the contribution of climate change-related hazards to humanitarian crises and conflict.

These harmful impacts have clear implications for the enjoyment, protection, and fulfillment of human rights. For example, the pervasive impacts of climate change on ecosystems and natural processes directly affect the right to a healthy environment; increases in the frequency and severity of extreme events and communicable diseases affect the rights to life and health, among others; and the inundation of low-lying islands and coastal areas, and subsequent displacement of people, has implications for a broad array of rights, including the rights to life, health, housing, property, food, water, culture, and self-determination. Table II.A.1 (next page) provides a more comprehensive list of human rights that are affected by climate change, accompanied by descriptions of relevant climate impacts, and citations to legal authorities finding that climate change poses a threat to the specific right.

Due to the breadth and magnitude of harm attributable to climate change, the UN High Commissioner for Human Rights has characterized climate change as the biggest threat to human rights that the world has ever seen.[136] The Inter-American Commission on Human Rights (IACHR) has also recognized that climate change "is one of the greatest threats to the full enjoyment and exercise of human rights of present and future generations."[137]

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[135] *See* IPCC AR6 WGII; IPCC 1.5°C REPORT.

[136] *See* Speech Michelle Bachelet, the UN High Commissioner for Human Rights, 42nd session of the Human Rights Council, https://www.ohchr.org/en/statements/2019/09/global-update-42nd-session-human-rights-council (declaring that "the human implications of currently projected levels of global heating are catastrophic" and that "the world has never seen a threat to human rights of this scope"). *See also* U.N. Human Rights Committee, General Comment No. 36 on Article 6: Right to Life, para 62, CCPR/C/GC/36 (Sept. 3, 2019), https://www.ohchr.org/en/calls-for-input/general-comment-no-36-article-6-right-life (characterizing climate change as one of the most pressing and serious threats to the ability of present and future generations to enjoy the right to life).

[137] IACHR Resolution 3/2021 at 8.

Table II.A.1. Scope of Human Rights Affected by Climate Change		
Affected Right	**Climate Impacts**	**Legal Authorities***
Right to life States have an affirmative obligation to protect the right to life from threats associated with climate change. (Am. Convention, Art. 4.)	• Mortality and morbidity from heatwaves, floods, and other climate extremes • Increased exposure to vector-, water-, and food-borne diseases • Food and water insecurity • Destruction of ecosystem services that people depend on for subsistence and survival • Humanitarian crises, conflict, and forced displacement	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN Human Rights Council (HRC), Human Rights and Climate Change, A/HRC/Res/10/4; UN Office of the High Commissioner for Human Rights (OHCHR), Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61; Views adopted by the UN Human Rights Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019, CCPR/C/135/D/3624/2019; UN Human Rights Committee (CCPR), General Comment No. 36 on Article 6: Right to Life, CCPR/C/GC/36; UN Committee on the Rights of the Child (CRC), General Comment No. 26 (2023) on children's rights and the environment, with a special focus on climate change, CRC/C/GC/26 • Urgenda v. Netherlands; Neubauer v. Germany; VZW Klimaatzaak v. Belgium; Future Generations v. Ministry of Environment; Klimatická žaloba ČR v. Czech Republic
Right to a safe, clean, healthy and sustainable environment States have an obligation to ensure that activities under their control do not cause significant environmental damage. (Protocol of San Salvador, Art. 11)	• Pervasive harm to terrestrial, marine, and freshwater ecosystems across the planet • Irreversible impacts on vulnerable ecosystems and species, including coral reefs, low-lying coastlines and islands, polar and mountain regions, biodiversity hotspots, endemic species, and many others • Destruction of coastal habitats as a result of sea level rise	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, The Human Right to a Clean, Healthy, and Sustainable Environment, A/HRC/RES/38/13 • UN General Assembly, The Human Right to a Clean, Healthy and Sustainable Environment, A/RES/76/300; UN CRC, General Comment No. 26 (2023) on children's rights and the environment, with a special focus on climate change, CRC/C/GC/26 • Klimatická žaloba ČR v. Czech Republic; Greenpeace Mexico v. Ministry of Energy and Others (on the National Electric System Policies)
Right to health States must take measures to ensure that all people enjoy the highest level of physical, mental, and social well-being. (Protocol of San Salvador, Art. 10)	• Mortality, injury, and trauma from extreme events (including mental trauma) • Exposure to vector- water- and food- borne diseases • Injury and mortality from food and water insecurity • Disruptions to livelihoods and cultural practices • Impaired ecosystem services • Humanitarian crises, conflict, and forced displacement	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, Analytical Study on the Relationship Between Climate Change and the Human Right of Everyone to the Enjoyment of the Highest Attainable Standard of Physical and Mental Health, A/HRC/32/23; UN HRC, Resolution: Human Rights and Climate Change, A/HRC/Res/10/4; UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/6; UN CRC, General Comment No. 26 (2023) on children's rights and the environment, with a special focus on climate change, CRC/C/GC/26 • Neubauer v. Germany, Klimatická žaloba ČR v. Czech Republic; Future Generations v. Ministry of Environment (Colombia)

Table II.A.1. Scope of Human Rights Affected by Climate Change (continued)		
Right to food States must take measures to ensure that all people have access to nutrition which guarantees the possibility of enjoying the highest level of physical, emotional, and intellectual development. (Protocol of San Salvador, Art. 12)	• Agricultural production is threated by extreme heat, drought, changes in precipitation, ecosystem degradation, and other impacts • Fishery productivity is threatened by ocean acidification, marine heatwaves, deoxygenation, and corresponding ecosystem impacts (e.g., coral reef destruction)	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, Report of the Secretary General: The Adverse Impact of Climate Change on the Full Realization of the Right to Food, A/HRC/53/47 • UN HRC, Resolution: Human Rights and Climate Change, A/HRC/Res/10/4; UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61 • Future Generations v. Ministry of Environment
Right to water and sanitation States must make efforts to ensure access to safe drinking water and sanitation services for present and future generations. (The Human Right to Safe Drinking Water and Sanitation, AG/RES. 2760 (XLII-O/12))	• Decreases in average precipitation and more severe droughts contribute to water shortages • Sea level rise causes saltwater intrusion into freshwater resources on islands and in other low-lying areas • Extreme events, including heavy precipitation and storms, pose hazards to water and sanitation systems	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, Resolution: Human Rights and Climate Change, A/HRC/Res/10/4; UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61
Right to housing and shelter States must make efforts to ensure adequate housing for all sectors of the population. (OAS Charter; American Declaration on the Rights and Duties of Man)	• Homes destroyed by extreme events such as floods, storms, and wildfires • Homes destroyed due to sea level rise • Access to shelter needed to protect people from extreme heat, storms, and other hazards associated with climate change	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, Resolution: Human Rights and Climate Change, A/HRC/Res/10/4; UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61
Right to work and livelihoods States must protect and promote the right to work, which includes the opportunity to secure the means for living a dignified and decent existence, as well as access to just, equitable, and satisfactory conditions of work. (Protocol of San Salvador, Arts. 6-7)	• Climate change threatens the livelihoods of many people, particularly subsistence farmers, fishermen, and others who depend on local ecosystem services • Extreme heat and other extreme weather conditions threaten the safety and well-being of workers, particularly outdoor workers and indoor workers without access to A/C in hot climates	• UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61 • Klimatická žaloba ČR v. Czech Republic
Right to property States may not arbitrarily deprive people of their property. (Am. Convention, Art. 21)	• Extreme events and slow-onset processes such as sea level rise threaten private property	• Neubauer v. Germany, Klimatická žaloba ČR v. Czech Republic

Table II.A.1. Scope of Human Rights Affected by Climate Change (continued)

Rights to private and family life States may not arbitrarily interfere with private, family, and home life, and must take steps to safeguard the ability of people to form families and provide for children. (Am. Convention, Art. 11; Protocol of San Salvador, Art. 15)	• Most climate change-related injuries have the potential to affect private and family life • Key examples include people who are displaced or at risk of displacement, people whose health and livelihoods are adversely affected by climate change, and people who are unable to pursue cultural and spiritual practices due to the effects of climate change	• UN CCPR, Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019, CCPR/C/135/D/3624/2019 • Urgenda v. Netherlands, VZW Klimaatzaak v. Belgium; Klimatická žaloba ČR v. Czech Republic
Rights to culture, self-determination, and development States must take steps to safeguard the ability of all people to take part in cultural practices and community life, as well as the rights of people to self-determination and development. (Am. Convention, Art. 26; Protocol of San Salvador, Art. 14; Am. Declaration on the Rights of Indigenous Peoples)	• Many Small Island States and indigenous peoples face severe threats to their culture, development, and self-determination due to the adverse effects of climate change • Some States and communities face existential risks due to climate change, e.g., low-lying coastal areas and islands are being inundated by sea level rise (and rapidly becoming uninhabitable) • Certain areas may become uninhabitable due to extreme heat, drought, and the destruction of food sources	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, Resolution: Human Rights and Climate Change, A/HRC/Res/10/4; UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61; UN CRC, General Comment No. 26 (2023) on children's rights and the environment, with a special focus on climate change, CRC/C/GC/26 • UN CCPR, Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019, CCPR/C/135/D/3624/2019 • Klimatická žaloba ČR v. Czech Republic
Rights to culture, self-determination, and development States must take steps to safeguard the ability of all people to take part in cultural practices and community life, as well as the rights of people to self-determination and development. (Am. Convention, Art. 26; Protocol of San Salvador, Art. 14; Am. Declaration on the Rights of Indigenous Peoples)	• Many Small Island States and indigenous peoples face severe threats to their culture, development, and self-determination due to the adverse effects of climate change • Some States and communities face existential risks due to climate change, e.g., low-lying coastal areas and islands are being inundated by sea level rise (and rapidly becoming uninhabitable) • Certain areas may become uninhabitable due to extreme heat, drought, and the destruction of food sources	• IACtHR Advisory Opinion OC-23/17 • IACHR Resolution 3/2021 • UN HRC, Resolution: Human Rights and Climate Change, A/HRC/Res/10/4; UN OHCHR, Report on the Relationship Between Climate Change and Human Rights, A/HRC/10/61; UN CRC, General Comment No. 26 (2023) on children's rights and the environment, with a special focus on climate change, CRC/C/GC/26 • UN CCPR, Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019, CCPR/C/135/D/3624/2019 • Klimatická žaloba ČR v. Czech Republic

Table II.A.1. Scope of Human Rights Affected by Climate Change (continued)		
Right to freedom, non-discrimination, and equity States must guarantee human rights without discrimination. (Protocol of San Salvador, Art. 3)	• Climate change causes disproportionate harm to certain groups (e.g., indigenous peoples), typically those who are least responsible for it • State failures to reduce GHG emissions in the near-term place a disproportionate burden on young people and future generations • Many buildings and other places of cultural significance are destroyed by flooding	• Neubauer v. Germany (finding that Germany had violated petitioners' right to freedom by adopting insufficient GHG reduction targets through 2030, which would place a disproportionate mitigation burden on German residents after 2030) • UN OHCHR, Frequently Asked Questions on Climate Human Rights and Climate Change: Fact Sheet No. 38 (2021); UN CRC, General Comment No. 26 (2023) on children's rights and the environment, with a special focus on climate change, CRC/C/GC/26
Rights of special groups States have special obligations regarding the protection of rights for certain groups. (Am. Declaration on the Rights of Indigenous Peoples; Protocol of San Salvador, Arts. 15-18.)	Groups and individuals that are disproportionately affected by climate change include: • Children • Women • Older people • Indigenous peoples • Poor people and socially marginalized groups • Subsistence farmers and fishermen • People living on small islands and in low-lying coastal areas • Displaced people and migrants • Future generations	• IACHR Resolution 3/2021 • UN HRC, The Impacts of Climate Change on the Human Rights of People in Vulnerable Situations, A/HRC/50/57; UN HRC, Analytical Study on the Promotion and Protection of the Rights of Older Persons in the Context of Climate Change, A/HRC/47/46; UN HRC, Analytical Study on the Promotion and the Protection of the Rights of Persons with Disabilities in the Context of Climate Change, A/HRC/44/30; UN HRC, Analytical Study on Gender-Responsive Climate Action for the Full and Effective Enjoyment of the Rights of Women, A/HRC/41/26; UN HRC, The Slow Onset Effects of Climate Change and Human Rights Protection for Cross-Border Migrants, A/HRC/37/CRP.4; Analytical Study on the Relationship Between Climate Change and the Full and Effective Enjoyment of the Rights of the Child, A/HRC/35/13; UN CRC, General comment No. 26 on children's rights and the environment with a special focus on climate change, CRC/C/GC/26.
* The "legal authorities" listed in this table are limited to decisions and declarations from human rights bodies, tribunals, and courts that explicitly recognize the threat posed by climate change to each specific right.		

B. The threat to human rights is both "actual" and "imminent"

The scientific research also shows that climate change poses a threat to human rights that is "actual" and "imminent", and not merely a future or hypothetical threat. In particular, impact attribution research provides ample evidence of rights-related injuries that have already occurred and are ongoing, and climate projections provide insights on foreseeable future injuries and when they may occur. For example, the research shows that many low-lying coastal areas and small islands are already experiencing acute impacts due to sea level rise and other coastal hazards, which cause direct harm to people, homes, and infrastructure, and also threaten the ecosystems upon which people depend.[138] Even under moderate emission scenarios, many small islands and coastal areas are projected to become uninhabitable by the end of the century, and some areas may become uninhabitable by mid-century or even earlier.[139] The IPCC estimates that approximately 896 million people (almost 11% of the global population) live in low-lying coastal zones that are affected and will be affected by sea level rise and other coastal hazards.[140]

Accordingly, courts and human rights tribunals have issued decisions recognizing that the injuries associated with climate change are sufficiently urgent and concrete to provide a basis for legal action. Even future harms may give rise to a legally cognizable injury. For example, in *Urgenda v. Netherlands,* the Supreme Court of the Netherlands found that future sea level rise "could render part of the Netherlands uninhabitable" and found that this constituted a violation of human rights even though "this risk will only be able to materialise a few decades from now and that it will not impact specific persons or a specific group of persons but large parts of the population."[141]

The decision in *Urgenda* dealt with the aggregate effects of climate change on Dutch citizens, rather than the effects on a specific set of plaintiffs. At that scale of analysis, there is little question that climate change poses an actual and imminent threat to rights. However, courts and tribunals may still confront factual disputes about whether and to what extent climate change threatens the rights of specific individuals or communities. The UN Human Rights Committee recently adjudicated one such dispute in *Billy et al. v. Australia,* where it held that the government of Australia had violated the rights of the indigenous Melanesian people of the Torres Strait Islands due to inadequate action on climate change (see Box II.A.2, next page).[142] Courts encounter these

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[138] *See* IPCC AR6 WGII, Ch. 15.

[139] Notably, researchers predict that low-lying areas and islands will become uninhabitable well before permanent inundation, due to the effects of sea level rise on extreme sea level events, freshwater supplies, and ecosystem services, among other things. *Id. See also* D.J. Rasmussen et al., *Extreme sea level implications of 1.5°C, 2.0°C, and 2.5°C temperature stabilization targets in the 21st and 22nd centuries,* 13(3) ENVIRO. RES. LETT. 034040 (2018), https://iopscience.iop.org/article/10.1088/1748-9326/aaac87 (comparatively small changes in mean sea level can result in large increases in the frequency of extreme sea level events, potentially rendering areas uninhabitable well before the time of permanent inundation); C. Storlazzi et al., *Most atolls will become uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding,* 4 SCIENCE ADVANCES eaap9741 (2018), https://www.science.org/doi/10.1126/sciadv.aap9741;

[140] IPCC AR6 WGII at 32, ¶ D.3.3.

[141] *Urgenda Foundation v. The State of The Netherlands*, *supra* note 134, ¶ 5.6.2.

[142] *Billy et al. v. Australia*, *supra* note 134.

types of disputes when adjudicating standing as well as the merits of claims – to guarantee access to justice, States and courts should ensure that petitioners have adequate opportunities to submit evidence in support of injury and causation before courts reach a definitive decision on standing.[143]

Box II.A.2. The UN Human Rights Committee's Decision in *Billy et al. v Australia*

In 2019, the Committee received a communication from indigenous Torres Strait Islanders alleging that the government of Australia had violated their rights to life, culture, privacy, home, and family life due to inadequate action on climate change. The authors described numerous ways in which climate change is affecting and will continue to affect their lives – e.g., sea level rise is causing flooding and erosion, property and ecosystem damage, inundating ancestral grave sites, and interfering with traditional gardening practices; higher temperatures and ocean acidification are causing coral bleaching, reef death, and the decline of sea-grass beds and other nutritionally and culturally important marine species; and changes in precipitation, temperature, and monsoon seasons have made it harder to pass on and subsist on their traditional ecological knowledge.[144] The islanders also face an imminent threat of forced and permanent displacement, as scientists predict that some islands are at "serious risk of becoming unfit for human habitation" in the near future (e.g., the next ten years) due to sea level rise and compounding storm surge events.[145]

Despite this information, the State of Australia insisted that the authors were merely asserting "future hypothetical violations" of rights because "the alleged adverse effects of climate change have yet to be suffered, if at all, by the authors."[146] The Committee rejected Australia's position and found that the Torres Strait Islanders had provided adequate evidence of "real predicaments that they have personally and actually experienced owing to disruptive climate events and slow-onset processes such as flooding and erosion… [that] have already compromised their ability to maintain their livelihoods, subsidence, and culture."[147] The Committee subsequently found that Australia had violated the authors' rights to privacy, home, and family life, and the right to indigenous culture, primarily due to the state's "failure to adapt" and protect the authors and their communities from harmful climate change impacts.[148]

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143 *See infra* § III.E.3 ("Access to Justice").

144 Communication Under the Optional Protocol to the International Covenant on Civil and Political Rights, *Billy et al. v. Australia*, CCPR/C/135/D/3624/2019 (13 May 2019).

145 *Id.* at ¶¶ 77-79; Annex 14 (full report).

146 State Party's Submission on Admissibility and Merits, *Billy et al. v Australia*, CCPR/C/135/D/3624/2019 (29 May 2020) at ¶¶ 24, 41.

147 *Billy et al. v. Australia, supra* note 134, at ¶ 7.10.

148 *Id.* at ¶ 9. The Committee did not find an imminent violation of the right to life in this particular case because the authors had not "indicated that they have faced or presently face adverse impacts to their own health or a real and reasonably foreseeable risk of being exposed to a situation of physical endangerment or extreme precarity that could threaten their right to life." *Id.* at para 8.6. It did, however, acknowledge that the authors' right to life would be violated if and when their islands become uninhabitable, but that there was time for Australia to implement adaptation measures that *may* be sufficient to protect that right. *Id.* at para 8.7 Several committee members published independent opinions in which they stated that they would have also found a violation of the right to life. *See* Annex III: Joint opinion by Committee Members Arif Bulkan, Marcia V.J. Kran and Vasilka Sancin (partially dissenting); Opinión individual del miembro del Comité Hernán Quezada (parcialmente disidente).

C. Climate change disproportionately affects certain groups and individuals

IPCC AR6 and other scientific authorities have found that climate change has disproportionate effects on certain individuals and groups, including children, women, the elderly, poor people, disabled people, indigenous peoples, subsistence farmers and fishermen, people living in informal settlements, and people who are already face social marginalization or vulnerability due to pre-existing inequalities and discrimination.[149] In many cases, those who suffer the greatest harms from climate change are also those who have contributed the least to this problem through GHG emissions, and who have fewer resources at their disposal for adaptation and resilience measures.[150] Some of examples of those who are disproportionately affected include:

- **Indigenous peoples:** Many indigenous communities are uniquely affected by changes in weather patterns, extreme events, and ecological disruptions due to their close connection to and dependence on local ecosystems and natural processes for subsistence, cultural practices, and livelihoods.[151] Some indigenous communities face the risk of forced displacement due to sea level rise, food and water insecurity, and other climate change-related phenomena.[152] This adversely affects indigenous peoples' rights to culture, self-determination, and territorial integrity, as well as those rights shared by all people (e.g., the rights to life and health).[153]
- **Children:** Children are uniquely vulnerable to many of the adverse health effects associated with climate change, including extreme heat, infectious diseases, food and water insecurity, and increases in air pollution (e.g., from wildfire smoke and increased ground

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[149] See, e.g., IPCC AR6 WGII at 1692, 1765; E.B. Barbier & J.P. Hchard, *The Impacts of Climate Change on the Poor in Disadvantaged Regions,* 12(1) REV. ENVIRON. ECON. POLICY 26 (2018), https://www.journals.uchicago.edu/doi/full/10.1093/reep/rex023; E. Parraguez-Vergara et al., *Impacts of Climate Change in the Andean Foothills of Chile: Economic and Cultural Vulnerability of Indigenous Mapuche Livelihoods,* 32(4) J. DEV. SOC. 454 (2016), https://journals.sagepub.com/doi/abs/10.1177/0169796X16667874.

[150] "Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (high confidence)." IPCC AR6 SYR SPM at page 5, para A.2.

[151] For example, increased ocean temperature and acidity are dominant drivers of coral reef death, which has enormous implications for the subsistence needs and cultural practices of many coastal communities. One recent study found that 50% of the world's coral reef ecosystems have been lost since 1950. Tyler D. Eddy et al., *Global Decline in Capacity of Coral Reefs to Provide Ecosystem Services,* 4(9) ONE EARTH P1278 (2021), https://www.sciencedirect.com/science/article/pii/S2590332221004747.

[152] *See* Rights of Indigenous People in Addressing Climate-Forced Displacement, Complaint Submitted to U.N. Special Rapporteurs (January 15, 2020), https://climatecasechart.com/non-us-case/rights-of-indigenous-people-in-addressing-climate-forced-displacement/.

[153] *See* American Declaration on the Rights of Indigenous Peoples (2016), Art. III (self-determination and cultural development), Art. IV (territorial integrity), Art. VI (collective right to culture); Art. XIII (cultural identity and integrity), https://www.oas.org/en/sare/documents/DecAmIND.pdf.

level ozone during hot temperatures).[154] In addition, children are uniquely vulnerable to stress and trauma from extreme events, displacement, and other harmful impacts. Children will also experience increasingly severe impacts from climate change during their lifetimes, as compared with adults. These impacts threaten children's rights to physical development, adequate nutrition, and all other core human rights.[155] The UN Committee on the Rights of the Child (CRC) has characterized climate change as a form of "structural violence against children" and a significant threat to children's rights, and has recognized a corresponding obligation on the part of States to ensure a clean, healthy and stable environment (and climate system) to respect, protect, and fulfill children's rights.[156]

- **Women and mothers:** Climate change also poses unique risks to the health and safety of women, especially mothers. For example, research has shown that women and girls are more likely to die in heatwaves, tropical cyclones, and other extreme events in certain countries, and they are more likely to suffer poor mental health, partner violence, and food insecurity following extreme weather and other environmental shocks.[157] Pregnant and breastfeeding mothers are also uniquely vulnerable to environmental hazards such as extreme heat and wildfire smoke. Climate change thus threatens women's right to gender equity as well as the rights of mothers to "special care and assistance" before and after childbirth.[158]

- **Inhabitants of small islands:** Small islands and their inhabitants are among the most vulnerable and acutely affected by climate change, as they are already experiencing acute burdens due to rising sea levels and other coastal hazards, their adaptation options are limited, and many islands face an existential threat due to sea level rise and its effects on habitability.

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[154] *See* Council on Environmental Health, *Global Climate Change and Children's Health,* 136(5) Pediatrics 992 (2015), https://pubmed.ncbi.nlm.nih.gov/26504130/; EPA, *Climate Change and Children's Health and Well-Being in the United States* (2023), https://www.epa.gov/cira/climate-change-and-childrens-health-and-well-being-united-states-report.

[155] Protocol of San Salvador Arts. 15, 16. *See also* UN Committee on the Rights of the Child (UN CRC), General Comment No. 26 (2023): Children's rights and the environment with a special focus on climate change, https://www.ohchr.org/en/documents/general-comments-and-recommendations/general-comment-no-26-2023-childrens-rights-and.

[156] UN CRC, General Comment No. 26 (2023), *supra* note 155. *See also* Held v. Montana, CDV-2020-307 (Mont. Dist. Ct. Aug. 14, 2023), https://climatecasechart.com/case/11091/ (finding that children are "uniquely vulnerable to the consequences of climate change, which harms their physical and psychological health and safety, interferes with family and cultural foundations and integrity, and causes economic deprivations," Findings of Fact, ¶ 104; that the "physical and psychological harms are both acute and chronic" and accrue from many different types of climate change impacts, Findings of Fact, ¶ 108; that youth plaintiffs had proven that they were disproportionately harmed by climate impacts such that they had standing to sue the State of Montana for its climate policies; Conclusions of Law, ¶ 8; and that the State had violated the plaintiffs' rights to a clean and healthy environment by enacting a statute that prohibited analysis and disclosure of GHG emissions under the State's environmental review procedures, Order, ¶ 6).

[157] Carbon Brief, *How Climate Change Disproportionately Affects Women's Health* (October 29, 2020), https://www.carbonbrief.org/mapped-how-climate-change-disproportionately-affects-womens-health/ (discussing findings from 130 studies on the gendered aspects of climate change).

[158] American Convention on Human Rights, Art. 1; Protocol of San Salvador, Art. 15(3)(a).

- **Future generations:** Future generations will suffer more extreme impacts as a result of climate change, and will also experience a much greater burden with regards to future GHG emissions reductions and adaptation if States do not undertake ambitious action now to control climate change. Future generations are entitled to human rights protections on the basis of international law, customary law, and treaty law,[159] and the Inter-American Democratic Charter explicitly recognizes that environmental protection is "essential" to protect the interests of both current and future generations.[160] Accordingly, this Court has also recognized that the human right to a healthy environment is "owed to both present and future generations."[161]

[159] Maastrict Principles on the Human Rights of Future Generations (adopted February 3, 2023).

[160] Inter-American Democratic Charter, adopted at the first plenary session of the OAS General Assembly on September 11, 2001, during the twenty-eighth period of sessions, Art. 15.

[161] Advisory Opinion OC-23/17 at ¶ 59.

III. State Obligations to Protect Human Rights in the Context of Climate Change

The Request raises questions about the nature of State obligations to prevent, minimize, provide redress for, and otherwise respond to the harmful effects of climate change within the framework of human rights law. This section describes how climate science can factor into the Court's assessment of State obligations related to: (a) climate change mitigation, (b) climate change adaptation, (c) international cooperation and climate finance, (d) compensation for loss and damage, and (e) government procedures (including those related to access to information, public participation, and access to justice). There are a number of principles from human rights law, international law, and treaty law that are relevant to this assessment (see Table III).

Table III. Sources of Law Relevant to Assessing State Obligations and Climate Change

Source of Legal Obligation	State Duty	Legal Authorities
Obligations to Respect, Protect and Guarantee Human Rights	In accordance with their customary and treaty obligations to respect and protect human rights, States must take action to limit their contributions to climate change, and otherwise safeguard human rights from threats associated with climate change. States are responsible for harm attributable to their GHG emissions, including extraterritorial harm.	See Table II.A.1, "Scope of Human Rights Affected by Climate Change"
United Nations Framework Convention on Climate Change (UNFCCC) (and see below)	State parties have agreed to "preserve the climate system for the benefit of present and future generations" and to "prevent dangerous anthropogenic interference with the climate system" by limiting global warming to "well below" 2°C or 1.5°C above pre-industrial levels. Accordingly, State parties have made commitments related to GHG mitigation, adaptation, information collection and disclosure, and international cooperation (including support to developing countries).	UNFCCC; Paris Agreement; UNFCCC COP Decision Documents; State-specific commitments articulated in Nationally Determined Contributions (NDCs)
Principle of Common but Differentiated Responsibilities and Respective Capabilities (CBDR)	This principle recognizes that State obligations with regards to collective problems like climate change should be interpreted in light of: (i) the State's specific contribution to the problem, and (ii) the State's capacity to respond to the problem. Accordingly, wealthier countries that have contributed more to climate change should take the lead in combating climate change and its adverse effects. The CBDR principle underpins discussions about States' "fair share" obligations with regards to GHG emission reductions and climate finance.	UNFCCC Art 3(1); Paris Agreement Art. 4; Stockholm Declaration of the United Nations Conference on the Human Environment (1972); Rio Declaration on Environment and Development (1992), Principle 15

Table III. Sources of Law Relevant to Assessing State Obligations and Climate Change (cont'd)		
The "No Harm" Rule and Duty to Prevent Transboundary Harm	States must undertake due diligence to ensure that activities carried out within their jurisdiction or under their effective control do not harm the environment and territory of other States. This obligation extends to GHG emissions and their extraterritorial effects.	UNFCCC; Paris Agreement; Stockholm Declaration; Rio Declaration Principles 12 and 19; IACtHR Advisory Opinion OC-23/17 §C
Precautionary Principle	States should take a precautionary approach in the context of scientific uncertainty. In the context of climate change, this means that States should take actions to reduce GHG emissions in order to prevent or minimize potential harms from climate change even where there is uncertainty about the precise scope, nature, or timing of those harms.	UNFCCC Art. 3; Rio Declaration Principle 15; IACtHR Advisory Opinion OC-23/17 § B.2
Duty to Cooperate and Principle of Solidarity	States have a duty to cooperate when implementing international agreements and addressing international problems. States also have an obligation to assist other States without expectations of reciprocity, in order to address shared problems such as climate change. These two principles are closely related to the CBDR principle – i.e., wealthier nations have an obligation to provide financial assistance to those who are disproportionately affected by climate change, without expectation of reciprocity.	UNFCCC Art 3; Paris Agreement Art. 6; Rio Declaration Principle 5; American Convention, Art. 26; UN General Assembly, Resolution 3281 (XXIX): Charter of Economic Rights and Duties of States (12 December 1974), Art. 3; IACtHR Advisory Opinion OC-23/17 § B.3
Equity Under International Environmental Law	The principle of equity means that decisionmakers should account for considerations of justice and fairness in the establishment, operation or application of a rule of law. Again, this is closely related to the CBDR principle – e.g., the Paris Agreement shall "be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." Art. 2(2).	UNFCCC Art. 3; Paris Agreement Arts. 2.2 & 4; Stockholm Declaration, Principles 1 & 12; Rio Declaration Principles 6 & 3; Johannesburg Declaration on Sustainable Development (2022)
Intergenerational Equity and Rights of Future Generations	This principle holds that there should be equity in the distribution of development benefits and burdens between different generations. Accordingly, legal scholars have recognized that future generations are legally entitled to human rights in accordance with international and humanitarian legal norms.	UNFCCC Art. 3, Paris Agreement preamble, Stockholm Declaration Principle 1; Rio Declaration Principle 3; Inter-American Democratic Charter (2001), Art. 15; IACtHR Advisory Opinion OC-23/17 ¶ 59; Maastricht Principles (2023)
Note: This table is adapted from the Sabin Center's *Status Report on Principles of International and Human Rights Law,* which contains a more comprehensive discussion of each principle and relevant legal authorities.[162] The *Status Report* is included as an attachment to this brief.		

[162] Katelyn Horne, Maria Antonia Tigre, and Michael B. Gerrard, *Status Report on Principles of International Law and Human Rights Law Relevant to Climate Change* (Sabin Center for Climate Change Law, 2023), https://scholarship.law.columbia.edu/faculty_scholarship/3924/.

A. Mitigation Obligations

The Request seeks clarification on the nature of State duties to prevent harm and guarantee human rights, including the rights to life and a clean environment, in the face of climate change.[163] A number of legal authorities have found that States have an obligation to control and reduce GHG emissions from sources under their jurisdiction to prevent harm and protect fundamental human rights.[164] This obligation is rooted in principles of human rights law, international law, and treaty law, as well as domestic constitutional law, and is often assessed in relation to standards articulated in UNFCCC agreements. For example, courts have held that States must adopt GHG mitigation policies that reflect a fair share of the mitigation effort required to limit global warming to 1.5°C-2°C, consistent with the principle of common but differentiated responsibilities and respective capabilities (CBDR), and that State GHG reduction measures must be at least as ambitious as State commitments made pursuant to the UNFCCC, Paris Agreement, Nationally Determined Contributions (NDCs), and regional climate agreements.[165]

Climate science serves as the principal evidentiary basis for characterizing State obligations with regards to GHG emission reductions and determining whether States have breached those obligations. As detailed below, the science provides core factual support for the general finding that states share responsibility for climate change and therefore have a "common" obligation to reduce GHG emissions. It also provides insights on the speed and scale at which GHG emissions

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[163] Request for Advisory Opinion, § IV(A)-(B).

[164] *See, e.g.,* IACHR Resolution 3/2021; *Urgenda v. Netherlands*, *supra* note 134; *Future Generations v. Ministry of the Environment and Others*, *supra* note 134; *Neubauer, et al. v. Germany*, *supra* note 134; *VZW Klimaatzaak v. Kingdom of Belgium & Others*, *supra* note 134; *Klimatická žaloba ČR v. Czech Republic*, *supra* note 134; *PSB et al. v. Brazil, supra* note 134; UN CRC, General Comment No. 26 (2023), *supra* note 155.

[165] *See, e.g., Urgenda v. Netherlands*, *supra* note 134 (ordering the Dutch government to limit GHG emissions to 25% below 1990 levels by 2020, consistent with UNFCCC and European Union (EU) targets, in order to protect rights to life and privacy); *Neubauer v. Germany*, *supra* note 134 (ordering the German government to enact policies aimed at achieving, at minimum, a 65% reduction in GHGs from 1990 levels by 2030, consistent with UNFCCC and EU targets, to protect rights to life, health, property, freedom, and intergenerational equity); *Future Generations v. Colombia*, *supra* note 134 (ordering the Colombian government to reduce deforestation in the Amazon, consistent with its NDC commitments); *VZW Klimaatzaak v. Belgium*, *supra* note 134 (finding that the Belgium government had breached its duty to protect rights to life and privacy due to inadequate ambition in GHG mitigation, but declining to set a GHG reduction target) (currently on appeal); *Klimatická žaloba ČR v. Czech Republic*, *supra* note 134 (ordering the Czech government to reduce GHGs by 55% in 2030 compared to 1990, based on the Paris Agreement and EU climate law) (remanded on appeal for additional clarification on the nature of plaintiffs injuries, and reconsideration of remedy); *PSB v. Brazil (on Climate Fund)*, *supra* note 134 (holding that the Brazilian government must execute and allocate its Climate Fund to mitigate GHG emissions and protect the right to a healthy environment, that it must avoid the regression of environmental protection, and that domestic laws must be consistent with the Paris Agreement and Brazil's NDC).

must be reduced in order to limit global warming to 1.5 or "well below" 2°C and the emission sources that States must regulate in order to achieve these targets. Finally, the research provides insights on the relative contributions of States to climate change and injuries attributable to climate change, which is relevant when assessing States' "differentiated responsibilities" (i.e., "fair share" obligations) with respect to GHG mitigation.

1. <u>All States share responsibility for climate change</u>

It is generally understood, as a matter of both human rights law and international environmental law, that States have responsibility for GHG emissions from sources that are under their jurisdiction or control. This basic understanding is at the heart of the CBDR principle as well as legal decisions finding that States have an obligation to reduce GHG emissions, and eventually reach net zero emissions, in order to protect human rights.[166] It is also consistent with the general principle that States are responsible for transboundary environmental harm originating from sources under their jurisdiction or control.[167]

Nonetheless, some States have argued that it is not possible, as a legal matter, to attribute climate change to any particular State due to the collective and cumulative nature of the problem.[168] This position is at odds with legal precedent as well as the basic science of climate change, which shows that there is a causal nexus between the emissions attributable to a State and the harmful effects of climate change. Every unit of GHGs that is emitted into the atmosphere contributes to climate change, and although no one State can totally prevent climate change, every State measure that results in GHG reductions will help mitigate the harmful effects of climate change.

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[166] *See* cases cited *supra* FN 165.

[167] IACtHR Advisory Opinion OC-23/17 (15 November 2017), § VII.C ("Obligations regarding transboundary damage"). *See also The South China Sea Arbitration (The Republic of Philippines v. The People's Republic of China)*, PCA Case No. 2013-19, Award (July 12, 2016), https://pca-cpa.org/en/cases/7/, ¶ 941 ("The corpus of international law relating to the environment… requires that States ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control.")

[168] For example, in response to the complaint filed by Torres Strait islanders, the government of Australia claimed that there was no "meaningful causation or connection between the alleged violations of their rights and the State party's measures or alleged failure to take measures." *Billy et al. v. Australia, supra* note 134, at ¶ 4.2. Australia even went so far as to claim, as a general matter, that "it is not possible under international human rights law to attribute climate change to a state party. As a legal matter, it is not possible to trace causal links between the State party's contribution to climate change, its efforts to address climate change, and the alleged effects of climate change on the enjoyment of other's rights." *Id.* at ¶ 4.3

As discussed in Part I, scientists and economists have even developed techniques for quantifying State contributions to certain types of climate impacts – these include social cost of GHG metrics, and attribution techniques that can be used to quantify contributions to specific events, impacts, and processes. However, courts have never required that level of granularity or precision to support a determination of State responsibility for climate change mitigation. Rather, courts have found that responsibility exists based on the general causal link between GHG emissions and climate change, the State's contribution to GHG emissions, and the extensive evidence of harmful impacts that are occurring as a result of climate change.[169]

Climate science thus provides support for the legal determination that all States share responsibility for climate change, as a result of GHG emissions under their effective control, and therefore have a common obligation to prevent climate change-related injuries by taking action to limit and reduce those emissions. The fact that climate change is a collective and cumulative problem does not in any way relieve States of that responsibility. Rather, this fact reinforces another dimension of State responsibility in this area – specifically, that States have an obligation to cooperate in order to reduce global GHG emissions, consistent with the principle of solidarity. Indeed, this Court and other legal authorities have recognized that States have a general duty to cooperate to address environmental harm, particularly transboundary harm like that associated with climate change.[170]

This Court has also recognized that States have an obligation to protect the human rights of people both within and outside of their territories.[171] Thus, State responsibility for GHG emissions – and the corresponding duty to mitigate – should be understood in relation to the full scope of harm attributable to those emissions, including harm that occurs outside of the State's territory. This is an important considering when assessing a State's "fair share" obligations.[172]

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[169] *See, e.g., Urgenda v. Netherlands, supra* note 134; *Neubauer v. Germany, supra* note 134. *See also* Held, *supra* note 156 (finding that the emissions attributable to the state of Montana contributed to climate change-related injuries incurred by plaintiffs, that the State had the authority to "alleviate and avoid climate impacts by limiting fossil fuel activities that occur in Montana", *Conclusions of Law* ¶14, and thus the plaintiffs had standing to sue the State for prohibiting consideration of GHG emissions in state environmental reviews).

[170] IACtHR Advisory Opinion OC-23/17, § VIII.B.3 ("Obligation of Cooperation"). *See also* American Convention, Art. 26 (establishing the obligation of international cooperation with a view to the development and protection of economic, social, and cultural rights).

[171] *Id.* at § VII.C.

[172] *See infra* § III(A)(3).

2. <u>States must achieve deep and rapid GHG reductions in the next decade to limit global warming to 1.5°C or "well below" 2°C</u>

It is clear that the window of opportunity to limit global warming to 1.5°C or "well below" 2°C is rapidly closing.[173] Meeting these temperature targets will require "rapid and deep and in most cases immediate GHG emission reductions across all sectors."[174] For example, based on emissions generated through 2019, IPCC AR6 found that emissions must peak before 2025 and then be reduced by roughly half by 2030 in order to have a >50% chance of limiting global warming to 1.5°C.[175] This may actually be an understatement of the ambition required to achieve the 1.5°C target, due to the fact that emissions have continued to grow since 2019. If these targets are exceeded, the impacts of climate change will be significantly worse, there will be an even greater need to rapidly reduce GHG emissions to protect human rights, some irretrievable tipping points will be crossed, and both mitigation and adaptation will become more costly.[176]

These findings support the IACHR's determination that States have an obligation to "adopt and implement policies aimed at reducing [GHG] emissions that reflect the *greatest possible ambition*"[177] – in other words, states must adopt policies and regulations aimed at reducing GHG emissions to net zero as quickly as possible, taking into account their respective capabilities and resources. This is consistent with the more general principle that states should guarantee human rights to the maximum extent possible,[178] as well as the precautionary principle, the "no harm" rule, the duty to prevent transboundary environmental harm, the duty to cooperate, and the CBDR principle.[179] Moreover, a principle of non-regression can be inferred from the obligation to pursue

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[173] *See infra* § I(B)(C). *See also* INTERNATIONAL ENERGY AGENCY, NET ZERO ROADMAP: A GLOBAL PATHWAY TO KEEP THE 1.5 °C GOAL IN REACH, 2023 UPDATE (September 2023), https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach.

[174] IPCC AR6 WGIII at 24.

[175] IPCC AR6 SYR Summary for Policymakers at ¶ B.6.1, Table SPM.1.

[176] *See, e.g.,* Benjamin M. Sanderson & Brian C. O'Neill, *Assessing the Costs of Historical Inaction on Climate Change*, 10 SCI. REP. 9173 (2020), https://www.nature.com/articles/s41598-020-66275-4 (finding that each year of delay in GHG mitigation can substantially increase the costs of mitigation).

[177] IACHR Resolution 3/2021 at 11.

[178] *See* IACtHR Advisory Opinion OC-23/17 at ¶ 118 (recognizing that "the obligation to ensure rights" means that States must take "all appropriate steps to protect and preserve" those rights).

[179] Preventative action is particularly warranted when confronting a problem like climate change, where there is ample evidence of foreseeable harm despite scientific uncertainty about some aspects of future impacts

the “greatest possible ambition” in GHG mitigation – i.e., States should not weaken mitigation policies unless there are compelling humanitarian circumstances requiring such action.[180]

As detailed below, scientific research also provides insights on how States can achieve GHG emission reductions at speed and scale, which is relevant when determining whether State policies reflect the greatest possible ambition with regards to climate change mitigation.

i. States must reduce emissions across all sectors and activities

To meet climate targets, States will need to reduce emissions across all sectors and sources, eventually achieving economy-wide net zero emissions. State mitigation obligations therefore encompass duties to reduce emissions from government activities, regulate emissions from private actors, and conserve and enhance carbon sinks and reservoirs, such as forests and coastal ecosystems.[181] Fossil fuel combustion for energy, transportation, and industrial use is by far the largest source of GHG emissions and should be a focal point of mitigation policies. Other major sources of emissions include agriculture, livestock production, waste and wastewater treatment, deforestation and land use change, and industrial process emissions. There are many actions that States can undertake to address emissions from these source categories, e.g.:[182]

- Adopting emission limits, performance-based standards, and/or price-based mitigation policies to control and reduce GHGs from fossil fuel-based energy and other sectors
- Ending fossil fuel subsidies, financing for fossil fuel projects, and other sources of public support for fossil fuel production, transportation, and consumption[183]
- Investing in renewable energy, and accelerating approvals for renewable energy projects and associated electricity storage and transmission infrastructure

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[180] *PSB v. Brazil*, *supra* note 134.

[181] *See, e.g., Future Generations v. Ministry of Environment* (Colombia), *supra* note 134, at ¶ 11.3 (finding that the government of Colombia had violated fundamental rights by allowing deforestation in the Amazon and abrogating its NDC commitment to reduce deforestation in the Colombian Amazon to zero by 2020 to prevent 44 megatons of GHGs from entering the atmosphere). *See also* Paris Agreement Art. 5.

[182] This list is based on recommendations from multiple legal and scientific sources, including the Deep Decarbonization Reports, *supra* note 131 (included as an attachment to this brief); LATIN AMERICAN ECONOMIC OUTLOOK 2022: TOWARDS A GREEN AND JUST TRANSITION (2022), https://www.cepal.org/en/publications/48415-latin-american-economic-outlook-2022-towards-green-and-just-transition; IMF, *Climate Change Challenges in Latin America and the Caribbean* (2021), https://www.imf.org/-/media/Files/Publications/REO/WHD/2021/English/CH3.ashx; Ken Alex, *What If We Really Acted as if Climate Change is An Emergency?*, LegalPlanet (July 5, 2023), https://legal-planet.org/2023/07/05/emergency/.

[183] Currently, Venezeula, Ecaudor, Bolivia, and Argentina net fossil fuel subsidies are equivalent to 85.6%, 29.2%, 23.5%, 15.4% respectively, of their health budgets. In total, the six countries spent USD 27.9 billion on fossil fuel subsidies in 2021. Hartinger et al. (2023), *supra* note 82, at 4.

- Adopting regulatory standards for or investing in energy efficiency
- Increasing access to low-carbon transportation options
- Ending deforestation and restoring and conserving habitats that serve as carbon sinks
- Establishing GHG control standards for agricultural and livestock practices
- Waste reduction and diversion strategies

State mitigation policies should be comprehensive, addressing all major emission sources within the country, based on the best available source attribution data (including data on carbon sinks and land use emissions). State mitigation policies should also be designed to achieve the maximum level of emission reduction (i.e., the greatest level of ambition), to the extent feasible and consistent with the CBDR principle, taking into account the best available research on the efficacy, feasibility, and cost of different mitigation technologies and policy pathways available to the State.

ii. States should reduce non-CO_2 emissions in order to limit near-term warming

Although CO_2 is the dominant cause of global warming, other GHG emissions have a more immediate and potent warming effect on a per ton basis. Methane, for example, has a global warming potential (GWP) of 82.5 over 20 years, meaning that one ton of methane causes 82.5 more warming than a ton of CO_2 in the 20 years after it is emitted.[184] Nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and chlorofluorocarbons (CFCs) are also highly potent GHGs.[185]

Especially given that there is a very real prospect of overshooting the 1.5°C target, states should aim to achieve reductions in these non-CO_2 pollutants in order to limit near-term warming to the maximum extent possible. Methane, in particular, plays a major role in short-term warming because methane emissions are so abundant.[186] Researchers have identified many different actions that states can undertake to reduce these more potent non-CO_2 emissions across sectors, including energy, agriculture, industry, and waste management.[187] Some of the most effective ways to reduce

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[184] IPCC AR6 WGI at 1017, Table 7.15

[185] The 20-year GWPs for these pollutants are: N2O (273), HFC-32 (2693), HFC (4144), CFC-11 (8231), PFC-14 (5301). IPCC AR6 WGI at 1017, Table 7.15 (note that these are average estimates).

[186] *See* IPCC AR6 WGIII at 23 (recognizing the potential to reduce peak warming through methane reductions).

[187] *See, e.g.,* Richard Ferris, Gabrielle Dreyfus, & Durwood Zaelke, *A Primer on Cutting Methane: The Best Strategy for Slowing Warming in the Decade to 2030* (Institute for Governance & Sustainable Development 2023), https://www.igsd.org/wp-content/uploads/2022/09/IGSD-Methane-Primer_2022.pdf (identifying technologies that can be used to achieve substantial reductions in methane emissions from the energy production, waste, and agriculture sectors).

methane emissions include: (i) phasing out fossil fuel production and consumption; (ii) requiring the use of technologies and operational practices to limit methane emissions from fossil fuel production and transportation systems; (ii) establishing standards for and/or making public investments in practices and technologies to reduce methane from livestock and agriculture (e.g., using anaerobic digestion to control methane from manure, daily spreading of manure and reducing long-term storage of manure), and reducing demand for livestock products; (iv) establishing standards for and/or making investments in practices and technologies to reduce methane from landfills and wastewater treatment facilities, and reducing waste production; and (v) implementing conservation and nature-based strategies to limit the release of biogenic methane from wetlands and other ecosystems.[188]

iii. States should pursue mitigation approaches that deliver co-benefits to marginalized and vulnerable populations

The Petition includes a question about what "differentiated measures" should be taken to minimize the impact of climate damages on "populations in situations of vulnerability," taking into account intersectional considerations.[189] As discussed below, adaptation approaches will be needed to minimize the effects of climate change on vulnerable populations, but States can also pursue GHG mitigation measures that have important co-benefits for vulnerable groups, in some cases even offsetting harmful impacts associated with climate change. For example, research on mitigation pathways indicates that the following measures would yield substantial co-benefits for vulnerable populations:

- Reducing fossil-fuel based road travel would help reduce mortality and illness associated with air pollution exposure, which disproportionately affects poor and marginalized communities in urban areas (e.g., it would help avert the over 10,100 deaths that were attributable to PM2.5 exposure from the transport sector in South America in 2020).[190]
- Providing access to clean cooking, heating, and household energy technologies, and reducing the use of traditional cookstoves that use charcoal, firewood, and other biomass would also help reduce mortality and illness associated with air pollution exposure that disproportionately affects people living in rural areas without access to electricity and/or

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[188] *See* Ferris et al. (2023), *supra* note 174; E.G. Nisbet et al., *Methane Mitigation: Methods to Reduce Emissions, on the Path to the Paris Agreement,* 58(1) REV. GEOPHYS. e2019RG000675 (2020), https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019RG000675.

[189] Request for Advisory Opinion at § IV(A)(2).

[190] Hartinger et al. (2023), *supra* note 82, at 4.

modern appliances. Public health data indicates that household air pollution from these polluting technologies was responsible for nearly 59,000 deaths in Latin America and the Caribbean in 2019 alone.[191]

- Nature- and ecosystem-based measures can enhance GHG sequestration while also providing environmental and adaptation benefits. For example, the protection of carbon sequestering ecosystems, such as forests, mangroves, and coastal wetlands, often improves resiliency to climate change-related hazards (e.g., tropical forests provide cooling benefits, mangroves and coastal wetlands reduce storm-related damages).[192] Planting trees and adding green surfaces to urban areas also sequesters carbon while mitigating the effects of extreme heat, storms, and floods, and providing air quality benefits.

3. <u>States' differentiated obligations should be interpreted in light of climate attribution research and carbon budget analyses</u>

Climate science also provides insights on States' "differentiated" responsibilities with respect to GHG mitigation. In particular, source attribution data and other areas of attribution research can be used to evaluate States' historical and present contributions to climate change and corresponding damages. This, in turn, can inform decisions about the equitable allocation of carbon budgets and what qualifies as a State's "fair share" of global mitigation efforts. We recognize that the Court has not been asked to characterize specific GHG reduction obligations for individual states, but the Request does seek clarification on the nature of State duties to prevent climate change and "what principles should inspire mitigation, adaptation and response actions to the losses and damages generated by the climate emergency."[193] It would therefore make sense for the Court to provide some generalized guidance on the nature of States' differentiated responsibilities with regards to GHG emissions and how scientific research may inform those responsibilities.

In prior rights-based litigation, courts and litigants have used attribution data to establish a causal connection between a state's GHG emissions, climate change, and adverse effects on

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[191] Astrid Schilmann et al., *Just and fair household energy transition in rural Latin American households: are we moving forward?* 16(10) ENVIRO. RES. LETT. 105012 (2021), https://iopscience.iop.org/article/10.1088/1748-9326/ac28b2.

[192] *See* P. Menéndez et al., *The Global Flood Protection Benefits of Mangroves*, 10 SCI. REP. 4404 (2020), https://www.nature.com/articles/s41598-020-61136-6; Frances Seymour et al., *Not Just Carbon: Capturing All the Benefits of Forests for Stabilizing the Climate from Local to Global Scales* (WRI 2022), https://www.wri.org/research/not-just-carbon-capturing-benefits-forests-climate; US National Ocean Service, *Coastal Blue Carbon*, https://oceanservice.noaa.gov/ecosystems/coastal-blue-carbon/.

[193] Request for Advisory Opinion, §§ IV(A)(1), IV(A)(2.B), IV(B)(1)(ii).

specific human rights.[194] However, courts have primarily relied on political documents, such as UNFCCC decisions, EU climate targets, and government-derived carbon budgets, when evaluating the sufficiency of GHG reduction targets and mitigation policies adopted by a State.[195] Courts have also referred to UNFCCC decisions and treaty commitments when evaluating the reasonableness of specific elements of State climate policies (e.g., policies related to the prevention of deforestation) and State obligations to implement existing policies..[196]

We recognize that the Court is not assessing the responsibility of any particular State with regards to GHG mitigation, but it is possible to articulate some general principles for assessing a State's differentiated responsibilities in this context. Based on a review of both scientific evidence and past litigation, we recommend the following general principles.

i. *State responsibility for climate change should be predicated on a holistic assessment of GHG emissions attributable to the State*

There are a number of different ways to attribute GHG emissions to a State. State responsibility for climate change is typically measured in reference to the State's territorial emissions (i.e., emissions from sources within the state). This has been the approach taken within the UNFCCC framework, and it has also underpinned various legal decisions on state responsibility for GHG mitigation.[197] However, different GHG accounting approaches provide valuable insights on the nature of State contributions to climate change, and the sufficiency or reasonableness of State mitigation measures. For example, data on consumption-based emissions provide insights on whether States are outsourcing carbon intensive products,[198] and data on fossil fuel production and extraction-based emissions provide insights on whether States are pursuing policies and development pathways that accord with the scientific consensus on the need to rapidly phase out

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[194] *See, e.g., Urgenda v. Netherlands, supra* note 134; *Neubauer v. Germany, supra* note 134; *VZW Klimaatzaak v. Belgium, supra* note 134; *Held v. Montana, supra* note 156.

[195] *Id.*

[196] *See, e.g., Future Generations v. Ministry of Enviroronment* (Colombia); *supra* note 134; *PSB v. Brazil, supra* note 134.

[197] *See* UNFCCC Reporting Requirements, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/reporting-requirements.

[198] *See, e.g.,* Zhan-Ming Chen et al., *Consumption-Based Greenhouse Gas Emissions Accounting with Capital Sock Highlights Dynamics of Fast-Developing Countries,* 9 NAT. COMMUN. 3581 (2018), https://www.nature.com/articles/s41467-018-05905-y; Michael Jakob & Robert Marschinski, *Interpreting Trade-Related CO_2 Emission Transfers,* 3 NAT. CLIM. CHANGE 19 (2013).

fossil fuels and leave most remaining reserves in the ground.[199] It is also informative to look at estimates of per capita emissions when assessing State mitigation obligations, since this metric accounts for differences in population among States and is relevant when considering what qualifies as an "equitable" distribution of emissions and mitigation effort. Granted, there are contexts where one accounting approach must prevail (e.g., when setting numeric GHG targets), but outside of those contexts, using multiple accounting methods provides more holistic insights on State responsibility for climate change.

State responsibility should also be assessed in light of the State's cumulative emissions (which can be measured in reference to territorial and/or per capita emissions), as this provides the best estimate of a State's total contribution to climate change and associated threats to human rights. States with larger emission contributions bear greater responsibility for climate injuries, and therefore have a greater obligation to control and reduce GHG emissions as quickly as possible, consistent with the CBDR principle.[200] This notion underpins much of the legal and technical discourse on whether States are doing their "fair share" to mitigate GHG emissions – although there is not a uniform definition of "fair share", it is clear that this concept refers to what "each country *should* be doing to reduce and reverse" its contribution to climate change, drawing on notions of equity and climate justice, and a State's cumulative emissions are clearly relevant to this analysis.[201] Granted, as discussed below, cumulative emissions are not the *only* factor that is relevant when framing fair share obligations (e.g., wealth and development status are also relevant). Moreover, States may be viewed as having greater responsibility with regards to recent and future emissions due to factors such as the foreseeability of harm from newer emissions, the ability of States to control current and future emissions, and the fact that more recent emissions may cause greater damage as they are less likely to be absorbed by ocean and terrestrial systems, and may cause the climate system to reach certain thresholds and tipping points.

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[199] *See, e.g., Held v. Montana*, Findings of Fact, ¶¶ 210-237 (estimating emissions attributable to fossil fuel extraction, processing, and transportation in Montana, and finding that these emissions were substantial enough to support State responsibility for plaintiff's climate-related injuries). *See also* Erickson & Lazarus (2013), *supra* note 98.

[200] *See* Paris Agreement Art. 4(4) (recognizing that "[d]eveloping country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets").

[201] Maria Antonia Tigre, *The 'Fair Share' of Climate Mitigation: Can Litigation Increase National Ambition for Brazil*, JOURNAL OF HUMAN RIGHTS PRACTICE (September 6, 2023), https://academic.oup.com/jhrp/advance-article-abstract/doi/10.1093/jhuman/huad032/7261647. *See also infra* § III.A.3.iii.

ii. State obligations are constantly evolving

States' "fair share" obligations are constantly evolving due to continued human interference with the climate system, the increasing urgency of GHG emission reductions, and new scientific information about the scope of harmful impacts attributable to climate change. In particular, as noted in Part I, it is possible that we will hit critical warming thresholds even faster than previously anticipated (e.g., exceeding the 1.5°C target within the next few years). Impacts may also be more harmful than anticipated, particularly if the world surpasses tipping points that result in cascading and compounding impacts, such as the melting of ice sheets. This means that GHG reduction targets need to be periodically re-assessed in light of new data about cumulative GHG emissions and the impacts attributable to those emissions.

For example, based on current emissions trajectories and scientific research on climate impacts, it is clear that emission reduction targets in UNFCCC documents and NDCs are not sufficiently protective of human rights.[202] These should therefore be viewed as a "floor" for state obligations – i.e., States must, at minimum, comply with NDC commitments and GHG reduction targets articulated in UNFCCC documents. Some States, particularly those that have made larger contributions to climate change, will need to pursue more ambitious GHG reduction targets in order to fulfill their human rights obligations. Of course, the adequacy of NDC commitments will vary depending on the level of ambition and the unique circumstances of the State.

iii. Carbon budget and "fair share" research can be used to assess the adequacy of state ambition

In light of the above considerations, courts may need to look beyond NDCs, UNFCCC documents, and other political agreements when assessing the adequacy of State ambition with regards to GHG reductions. As noted in Part I, there is a growing body of research on the equitable allocation of the global carbon budget that courts can refer to in order to determine whether a State is doing its fair share to reduce GHG emissions.[203] The research generally recognizes that historical responsibility (as measured by cumulative emissions), current levels of per capita emissions, and

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[202] *See* UNEP, EMISSIONS GAP REPORT 2022, https://www.unep.org/resources/emissions-gap-report-2022.

[203] *See, e.g.,* Rajamani et al. (2021), *supra* note 129; Hickel et al. (2020), *supra* note 129; Maria Antonia Tigre (2023), *supra* note 201; *Fair Shares: A Civil Society Equity Review of NDCs* (Civil Society Review 2015), https://policy-practice.oxfam.org/resources/fair-shares-a-civil-society-equity-review-of-indcs-579848/; Climate Action Tracker, *Fair Share*, https://climateactiontracker.org/methodology/cat-rating-methodology/fair-share/.

development status are all relevant when evaluating fair share obligations. State obligations should also be assessed in light of the overarching goal of harm prevention, i.e., they should reflect emission reduction pathways that have a reasonable chance of limiting global warming to 1.5°C or well below 2.0°C.

There is tension between the goals of harm prevention and international equity. The CBDR principle addresses this by acknowledging that States have a "common" obligation to reduce GHG emissions as rapidly as possible in order to mitigate the human rights consequences of climate change, but they also have "differentiated" obligations with regards to GHG reduction due to varying levels of responsibility for climate change as well as differences in wealth and development status. Courts will need to account for both types of considerations when evaluating fair share obligations for specific States.

Rajamani et al. (2021) demonstrate how fair share obligations can be assessed using the principles of international environmental law, including the principles of harm prevention, precaution, sustainable development, special circumstances, equity (inter- and intra-generational), CBDR, public participation, international cooperation and good faith.[204] The authors evaluate nationally determined contributions (NDCs) to the Paris Agreement in light of these principles, and find that NDCs are often predicated on a combination of indicators that both are and are not supported by the equitable principles of international environmental law (see Box III.A.3, next page). The authors also present a framework for quantifying fair-share contributions based on their assessment of legal principles and NDC indicators, and in accordance with a global emissions pathway that have a reasonable prospect of limiting warming to well below 2°C.

Importantly, even where a court lacks jurisdiction to establish numeric GHG reduction targets for a State, it can use carbon budget and fair share research to evaluate the sufficiency of existing targets and policies, and to determine whether more ambitious measures are needed to protect human rights.[205] For example, the framework articulated by Rajamani et al. could be used in qualitative assessments of NDC commitments and GHG reduction targets.

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[204] Rajamani et al. (2021), *supra* note 129.
[205] *See, e.g.,* Brussels Court of First Instance, *VZW Klimaatzaak v. Kingdom of Belgium & Others*.

Box III.A.3. Evaluation of NDC Indicators and Consistency with International Environmental Law in Rajamani et al. (2021)
Indicators supported by principles of international environmental law: • Emissions per capita (73) • Classification as small island developing states (SIDS) or least developed countries (LDCs) (61) • Small share of global emissions, to the extent this overlaps with special circumstances (ie., LDCs and/or SIDs) (59) • Historic responsibility (37) • GDP per capita (27)
Indicators not supported by principles of international environmental law: • Small share of global emissions for countries that are not LDCs or SIDs (52) • Progression of own effort (55) • In line with own targets (26) • Emissions per GDP (24) • Peak year (10) • Least cost pathways (8)
Notes: • The (##) next to each indicator refer to the number of NDCs that contained each indicator (specifically, NDCs submitted through December 31, 2020). • These indicators are based on the text of NDCs. The authors identify a number of other indicators that would also be consistent with the principles of international environmental law, including cumulative GHG emissions, current and projected harm, and GDP per capita adjusted for development.

iv. GHG reduction targets are not the only way to characterize State obligations with regards to GHG emissions

It is important to recognize that State obligations with regards to GHG emissions do not need to be exclusively framed in reference to numeric GHG reduction targets. The adequacy of a state's GHG reduction measures can also be assessed by evaluating the nature of state climate policies in light of the state's resources, development status, capacity constraints, and other considerations. For example, a court could evaluate whether a State is making its best efforts to transition its energy system away from fossil fuels and to reduce emissions from other key sectors, such as agriculture and land use. This would be generally consistent with how courts approach many legal disputes involving human rights – assessments of whether States are fulfilling their human rights obligations are often predicated on a more qualitative analysis of State measures and whether they reflect, e.g., "the greatest possible ambition," taking into account the respective capabilities of the

State.[206] Research on the efficacy, cost, and availability of mitigation technologies and policies would be relevant to such an analysis, as would source attribution research on GHG emissions from different sectors and activities under the State's jurisdiction or effective control.

A more qualitative or functional analysis of State action may also be necessary when courts are tasked with assessing the legality of policies and government decisions that contribute to climate change in ways that are not reflected in territorial emission budgets, e.g., decisions about fossil fuel extraction and export, land use decisions with difficult-to-quantify emissions impacts, or policies that may affect consumption-based emissions. In that context, courts can refer to available emissions data to understand the magnitude of the impact on climate change, but the legality of the action would ultimately need to be assessed in reference to something other than a territorial emissions budget (e.g., whether the State is taking reasonable measures or making "best efforts" to transition away from dependency on fossil fuel exports, mitigate emissions from deforestation or other land use decisions, prevent carbon leakage, etc.).

B. Adaptation Obligations

The Request also raises questions about the scope of state duties with regards to adaptation measures, minimizing the harms caused by climate change, and protecting vulnerable populations, such as children, from the impacts of climate change.[207] Human rights law recognizes an obligation on the part of States to take reasonable measures to protect and guarantee human rights in the face of foreseeable environmental risks and natural hazards, even where the State did not cause such hazards through its own actions.[208] Accordingly, States must prepare for and respond to the effects

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[206] *See, e.g., Future Generations v. Colombia, supra* note 134; *PSB v. Brazil, supra* note 134.

[207] Request §§ IV(A)(2); (IV)(B)(1)(ii)-(iii); (IV)(C)(1).

[208] For example, there are several decisions from the European Court of Human Rights (ECtHR) that provide insights on the nature of a state's positive obligation to protect the right to life in the context of natural disasters. In *Budayeva and Others* v. *Russia*, the ECtHR determined that Russian authorities had violated the right to life when those authorities knew that there was a risk of a mudslide but did not implement land planning and emergency relief policies or adequately inform the public about the risk, and eight citizens died as a result of the mudslide. *Budayeva and Others* v. *Russia*, App. Nos. 15339/02, 21155/02, 20058/02, 11673/02 and 1543/02, Eur. Ct. H.R. (March 20, 2008). Similarly, in *Kolyadenko* v. *Russia*, the ECtHR determined that Russian authorities violated the rights to life, respect for private and family life, and protection of property when they released a large amount of water from a reservoir during an exceptionally heavy rain event, thus causing a flash flood immediately downstream of the reservoir. *Kolyadenko and Others* v. *Russia*, Eur. Ct. H.R. (Judgment, February 28, 2012). Notably, the court did not find that authorities were negligent in their operation of the dam at the time of the flood – rather, the problem was that the government authorities (i) knew for many years that such an event was foreseeable and failed to take action to mitigate the risk, (ii) failed to adopt planning restrictions and take other necessary steps to protect people living downstream

of climate change, particularly those that pose a foreseeable threat to human rights, and this "duty of adaptation" is independent from State responsibility for GHG emissions and the duty of mitigation. Attribution research and climate projections provide insights on foreseeable hazards and risks associated with climate change and are therefore relevant when assessing State obligations to adapt.

1. Greater ambition in adaptation will be needed to protect human rights from the harmful impacts of climate change

The findings from IPCC AR6 and other scientific authorities indicate that ambitious adaptation measures will be needed to protect human rights from foreseeable threats associated with climate change, even if warming is limited to 1.5 or 2°C, and adaptation requirements will increase with each additional increment of warming. IPCC AR6 and other authorities have also found that current investments in adaptation are insufficient and "adaptation gaps" will continue to grow under current policies.[209] States will therefore need to enhance their ambition with regards to adaptation to protect people and ecosystems from climate change-related hazards that pose an imminent risk to life, health, environmental health, and other fundamental rights.

To date, court decisions involving human rights and climate change have focused on mitigation obligations for states, but courts are beginning to weigh in on the scope of state obligations with regards to climate change adaptation.[210] For example, courts in Colombia and Pakistan have

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of the reservoir, and (iii) did not take all possible measures to alert residents of the risks prior to or during the storm. There are also a number of human rights decisions affirming that governments have a positive obligation to protect citizens from other environmental hazards that threaten human rights, including wholly man-made hazards. For example, in *Öneryildiz* v. *Turkey*, the ECtHR found that the government of Turkey had violated the rights to life and property arising from a methane explosion at a landfill when governmental authorities knew of the risk of explosion but failed to issue any regulations or take measures to mitigate that risk. *Öneryildiz* v. *Turkey*, Eur. Ct. H.R. (Judgment, 2004) at 1. *See also The Environment & Human Rights*, Advisory Opinion OC-23/17, Inter-Am. Ct. H.R. (ser. A), No. 23 (holding that governments have a positive obligation to prevent foreseeable harms arising from their conduct).

[209] *See* IPCC AR6 SYR at ¶ A.3 ("Despite progress, adaptation gaps exist, and will continue to grow at current rates of implementation. … Current global financial flows for adaptation are insufficient for, and constrain implementation of, adaptation options, especially in developing countries (*high confidence*)."). *See also* UNEP, ADAPTATION GAP REPORT 2022 (Nov. 1, 2022).

[210] *See, e.g., Billy et al. v. Australia, supra* note 134*; Leghari v. Pakistan, supra* note 134. There are also a number of pending cases and petitions involving adaptation-oriented claims. For example, the US tribal petition to the UN Special Rapporteurs alleges that the US government and the state governments of Louisiana and Alaska violated the collective and individual rights of Indigenous tribes by (i) undertaking maladaptive activities that contributed to coastal erosion, land loss, and flooding along the coastlines where the tribes reside, thus exacerbating the effects of sea level rise and extreme storms; and (ii) failing to take affirmative measures to protect the tribes from sea level rise, extreme storms,

generally found that governments have an obligation to undertake adaptation measures in order to protect fundamental rights, such as the rights to life and environmental health.[211] The UN Human Rights Committee's decision in *Billy et al. v. Australia* is perhaps the strongest decision to date on State adaptation obligations under human rights law. The Committee specifically found that Australia had violated the Torres Strait Islanders' rights to indigenous culture and family, home, and private life because it "fail[ed] to discharge its positive obligation to implement adequate adaptation measures" to protect the authors and their communities.[212] Based on this holding, the Committee found that the State had obligations to, *inter alia,* "take measures necessary to secure the communities' continued safe existence on their respective islands," "provide adequate compensation, to the authors for the harm they have suffered," and "take steps to prevent similar violations in the future."[213]

Because petitioners do not need to prove that the government defendant caused or contributed to climate change in a failure-to-adapt case, the factual analysis is different from that in failure-to-mitigate cases. Petitioners need not grapple with questions about source attribution or related defenses. Instead, the focus is on the reasonableness of the government's response to climate change (or lack thereof), which is based, at least in part, on the nature of climate change impacts and whether they are (or were) foreseeable.

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and land loss and, in particular, failing to implement a "relocation governance framework" for these tribes. See Rights of Indigenous Peoples in Addressing Forced Displacement, supra note 152.

[211] *Future Generations v. Ministry of Environment & Others* (Colombia), *supra* note 134; Leghari v. Pakistan, *supra* note 134.

[212] The implications of the Committee's decisions for state mitigation obligations are unclear. Although the decision specifically referred to *adaptation* measures in the two paragraphs finding a violation of those rights, it did not explicitly reject the Islanders' claims with respect to mitigation, and some of the state obligations identified later in the decision could be interpreted as requiring both GHG mitigation and adaptation (e.g., the duty to prevent future harm). One committee member published an independent opinion expressing the view that the HRC should have linked the State obligation more clearly to mitigation measures, because adaptation will eventually become impossible for the islands in the absence of effective mitigation. (Annex II: Individual Opinion by Committee Member Gentian Zyberi (concurring), para 6). The committee member also noted that a "higher standard of due diligence applies in respect to those States with significant total emissions or very high per capita emissions (whether these are past or current emissions), given the greater burden that those emissions place on the global climate system, as well as to States with higher capacities to take high ambitious mitigation action." (id. at para 5).

[213] *Billy et al. v. Australia*, *supra* note 134, ¶ 11.

2. <u>Climate science provides actionable information on foreseeable climate hazards</u>

Attribution research and climate projections provide insights on the effects of climate change that are already underway, likely future effects under different warming scenarios, and the extent to which specific climate change-related risks are foreseeable and should therefore be taken into account by decision-makers. Although attribution research is most often invoked in legal discussions about responsibly for climate change, its ultimate aim is to "further scientific understanding of causal links between elements of the Earth system and society" and thus the research also supports "management of climate-related risks through improved understanding of drivers of relevant hazards, or more widely, vulnerability and exposure."[214]

For example, the research shows that certain natural hazards, which might be characterized as "unlikely" or "unforeseeable" in a world without climate change, are becoming much more prevalent, thus posing foreseeable risks that should be accounted for in government planning and decision-making processes.[215] The research also provides insights on the prominent climate change-related hazards in Latin America and the Caribbean, and suggests that adaptation measures are needed to: (i) mitigate the adverse effect of climate change on agricultural systems, food security, and water security; (ii) reduce exposure and vulnerability to extreme heat, storms, flooding, and landslides; (iii) conserve and restore key ecosystems, such as forests, mangroves, and coastal wetlands, in order to reduce ecological damage and preserve ecosystem services; (iv) expand health services and protective measures to address the increased prevalence of communicable diseases; and (v) address the effects of sea level rise and other coastal hazards on small islands and low-lying coastlines.

The IPCC reports are a useful starting point for identifying foreseeable climate impacts and appropriate adaptation measures, but it will typically be necessary to consult other scientific resources, such as regional climate impact and vulnerability assessments, for more granular data on the effects of climate change on specific communities, locations, sectors, and activities.[216]

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[214] Rachel A. James et al., *Attribution: How is it Relevant for Loss and Damage Policy and Practice?,* CLIMATE RISK MANAGEMENT, POLICY AND GOVERNANCE (2018), https://link.springer.com/chapter/10.1007/978-3-319-72026-5_5.

[215] For example, the "recurrence interval" for climate-related extremes is increasing in many regions, such that events which were previously viewed as very rare (e.g., 1-in-500 year storms) are now occurring much more frequently.

[216] *See supra* § I(A)(3). For examples of national climate impact and vulnerability assessments, see: Uruguay Ministerio de Ambiente, *Cambio Climático*, https://www.gub.uy/ministerio-ambiente/cambio-climatico; Chile,

3. Adaptation should be "mainstreamed" in government planning processes

Government decision-makers should account for climate change-related hazards and adaptation options across a wide array of decisions related to natural resource management, ecosystem and biodiversity protection, urban and rural planning, food and water security, public health, and much more. States and sub-state actors should therefore seek to integrate or "mainstream" adaptation planning into existing planning processes across these different areas of decision-making. For example, the legal frameworks for environmental impact assessments should be updated, where needed, to ensure that decision-makers are accounting for climate impacts and opportunities to mitigate risks or environmental hazards associated with climate change.[217]

C. International Cooperation and Climate Finance

The Request seeks clarification on the scope of state duties to prevent, minimize, and respond to the effects of climate change in the context of human rights law.[218] These duties encompass obligations related to international cooperation and the provision of climate finance. The IACHR and other legal authorities have recognized that States with greater financial capacity and greater responsibility for climate change have obligations to provide greater technical and logistical assistance for mitigation and adaptation activities in States that are most affected by climate change and have fewer resources to respond to it.[219] This obligation is predicated on the principles of

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Ministerio del Medio Ambiente, *Publicaticiones Destacadas*, https://cambioclimatico.mma.gob.cl/publicaciones-destacadas/. For other examples of regional and local climate impact studies, see José A. Marengo & Carlos Souza Jr., *Mudanças Climáticas: impactos e cenários para a Amazônia* (2018), https://www.oamanhaehoje.com.br/assets/pdf/Relatorio_Mudancas_Climaticas-Amazonia.pdf (evaluating the effects of climate change on biodiversity in the Amazon rainforest); Vanesa Londoño Arteaga & Carlos Henrique Ribeiro Lima, *Impacto das mudanças climáticas em índices de monção da América do Sul,* Brazilian Association of Water Resources, Presented at the XIII Brazilian Symposium on Water Resources (2019), https://files.abrhidro.org.br/Eventos/Trabalhos /107/XXIII-SBRH0668-1-20190808-101233.pdf (finding that climate change will likely affect circulation patterns over Brazil in ways that will cause intensification of wind and precipitation patterns, particularly during summer months); Giovanna Klautau Leite Costa et al., *Impacto das mudanças climáticas nas vazões mínimas de referência de pequenas bacias hidrográficas na Amazônia Legal e dentro do arco do desflorestamento*, (20) REVISTA DE GESTÃO DE ÁGUA DA AMÉRICA LATINA (2023), https://www.abrh.org.br/OJS/index.php/REGA/article/view/790/117 (finding that climate change may cause a drastic reduction in minimum reference flows of two small catchments located in the Amazon (Cerrado biome) and the Arch of Deforestation).

[217] *See infra* § III(E).

[218] Request for Advisory Opinion, §§ (IV)(A), (IV)(B).

[219] *See* IACHR Resolution 3/2021, Section C.II, para 10 ("States have an obligation to cooperate in good faith in order to prevent pollution of the planet, which entails reducing their emissions to ensure a safe climate that enables the

CDBR, international cooperation, and international solidarity.[220] It is also related to State obligations to mitigate environmental harm arising from activities under their effective control, insofar as financial assistance for adaptation can serve as a form of mitigation for damages attributable to a State's GHG emissions.[221] In other words, there is considerable overlap between State obligations related to climate finance and State obligations related to loss and damage.

Climate finance obligations should therefore be assessed in light of both the State's contributions to climate damages and the State's capacity to provide assistance. As discussed above, climate science, particularly detection and attribution research, provides critical insights on the first issue (State contributions to climate change) and can therefore inform assessments of whether State commitments to climate finance reflect an adequate level of ambition – e.g., finance commitments could be compared to estimates of economic damages attributable to the State. The scientific research also provides insights on where financial resources should be directed in order to achieve the greatest level of harm reduction and the greatest benefit to human rights – e.g., source attribution data can be used to determine where financial investments in GHG mitigation will deliver the largest GHG reductions at the lowest cost, and impact attribution data can be used to determine whether adaptation investments will yield the greatest benefits.

D. Compensation for Loss and Damage

The Petition raises questions about State obligations to address the losses and damages generated by climate change, particularly in relation to their individual and collective obligations to "guarantee the right to reparations for damages generated by their actions or omissions in the face of the climate emergency."[222] This Court has acknowledged that States have an obligation to

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exercise of rights. This involves exchanging resources, technology, knowledge and capacities to build societies that operate in a low-emission environment, move towards a clean and just energy transition, and protect people's rights. States that are in a position to do so should contribute to covering the costs of mitigation and adaptation of States prevented from doing so, in accordance with the principle of common but differentiated responsibilities. In general, the fundamental principles of climate justice should serve as a guide for international cooperation.") *See also id. at* Section C.1, para 7; UNHRC, Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment, A/74/161 (2019), ¶¶ 26 and 68 (recognizing that "wealthy States must contribute their fair share towards the costs of mitigation and adaptation in low income countries," through grants and not loans, given that basic principles of justice are violated when poor countries are forced to pay for "the costs of responding to climate change when wealthy countries caused the problem.").

[220] See Table III, *supra* page 38.

[221] *See* IACtHR Advisory Opinion OC-23/17 at ¶¶ 145, 172-173.

[222] Request for Advisory Opinion, §IV(F)(2).

mitigate environmental damage from activities under their control or jurisdiction, that this responsibility extends to extraterritorial harms and transboundary environmental damage,[223] and that violations of environmental and human rights "may result in sanctions as well as compensation for their negative consequences."[224] Accordingly, the Court has found that there are circumstances in which a State may be required to pay reparations to cover the costs of environmental damages and restitution.[225] However, we recognize that there are open questions about the nature of State obligations to provide compensation for loss and damage caused by insufficient action on climate and insufficient regulation of GHG emissions, as there are very few legal decisions on this topic.[226]

As noted above, the UN Human Rights Committee did recently issue a decision in which it recognized that the government of Australia had an obligation to pay damages to indigenous Torres Strait islanders due to the State's failure to protect the islanders from harmful effects of climate change, but this was premised on Australia's failure to adapt, rather than loss and damage deriving from Australia's contribution to climate change.[227] If a State's failure to adapt can give rise to a

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[223] IACtHR Advisory Opinion OC-23/17 at § C. *See also id.* at paras 145, 172-173.

[224] *Id.* at para 127.

[225] *See Lhaka Honhat (Our Land) Association v. Argentina*, Inter-Am. Ct. H.R. (ser. C.) No. 400 (Feb. 6, 2020), https://www.corteidh.or.cr/docs/casos/articulos/seriec_400_ing.pdf; Maria Antonia Tigre, *International Recognition of the Right to a Healthy Environment: What is the Added Value for Latin America and the Caribbean?* 117 AJIL UNBOUND 184 (2023), https://www.cambridge.org/core/journals/american-journal-of-international-law/article/international-recognition-of-the-right-to-a-healthy-environment-what-is-the-added-value-for-latin-america-and-the-caribbean/1DAC082B9E909B45E3FEADC89E4126D9.

[226] At this time, the question of state obligations to provide compensation for climate change-related loss and damage is primarily being addressed through political channels, particularly negotiations under the UNFCCC. In 2022, the UNFCCC COP established a loss and damage fund, providing further legitimacy to the notion that States with greater responsibility for climate change should compensate other States for climate change-related losses and damages. States may also have a legal obligation to provide compensation for climate change-related loss and damage based on principles of human rights law and international environmental law, particularly the obligation to provide restitution for environmental harm caused to another country. *See* Audrey Chapman & A. Karim Ahmend, *Climate Justice, Human Rights, and the Case for Reparations,* 23(2) HEALTH HUM. RIGHTS 81 (2021), https://pubmed.ncbi.nlm.nih.gov/34966227/; Margaretha Wewerinke-Singh, *Remedies for Human Rights Violations Caused by Climate Change*, 9 CLIM. LAW 224 (2019), https://brill.com/view/journals/clla/9/3/article-p224_224.xml.

[227] *Daniel Billy and others v. Australia*, *supra* note 134 (finding that Australia had violated the rights of indigenous Torres Strait Islanders by failing to take timely and adequate measures to protect them from climate change-related harms, and asking Australia to compensate the islanders for harm suffered and to take measures to secure their safe existence in the future). There are a number of other climate cases where plaintiffs are seeking restitution for losses and damages, but most of these cases involve non-state defendants (e.g., fossil fuel companies). *See, e.g., Lliuya v. RWE*, Az. 2 O 285/15 Essen Regional Court [2015], https://climatecasechart.com/non-us-case/lliuya-v-rwe-ag/; *Asmania et al., v. Holcim* (Switzerland 2022), https://climatecasechart.com/non-us-case/four-islanders-of-pari-v-holcim/.

duty to compensate injured parties, then presumably a State's contribution to climate change can also give rise to such a duty.

Loss and damage claims deal specifically with impacts and injuries that have already occurred as a result of climate change, and so attribution science is most relevant to such claims, as it can be used to calculate and attribute certain types of damages to specific sources. Some of the top-level findings from IPCC AR6 with regards to losses and damages are that: (i) human-induced climate change is already causing losses and damages to nature and people across the planet, (ii) losses and damages are unequally distributed across different countries, (iii) losses and damages will escalate with each increment of warming, (iv) losses and damages will continue to increase even with adaptation.[228] AR6 thus provides general support for the establishment of legal structures to address loss and damage.

As discussed in Part I, researchers have developed techniques for estimating losses and damages at different scales and for attributing those damages to specific States. For example, Callahan & Mankin (2022) provide estimates of each country's responsibility for temperature-driven income changes in all other countries. This type of data could be used to assess loss and damage claims between States. However, it is more difficult to estimate State contributions to climate damages incurred by individual rights-holders and communities. Generally speaking, confidence in attribution tends to be higher when evaluating changes and impacts at larger geographic and temporal scales, and there are additional complexities involved in "downscaling" attribution analyses to the level of an individual or community. At that scale, "there are multiple factors that contribute to a specific loss or damage, and the signal from climate change is more difficult to detect relative to the many other potential influences on hazard occurrence, exposure, and vulnerability."[229] Thus, although it is clear that State-level emissions contribute to local losses and damages from climate change, it may not be possible to assign a monetary value to all or most elements of that contribution, due to uncertainty about the influence of climate change at that scale, and the fact that many types of losses that cannot be readily be translated to a damage value.

Perhaps due to these challenges, the plaintiffs and petitioners in climate damage cases have sought compensation to help cover adaptation costs, in lieu of calculating actual damages

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[228] IPCC AR6 SYN SPM.

[229] James et al. (2018), *supra* note 214, at 115.

attributable to climate change. This has been the approach in lawsuits filed against private companies, primarily fossil fuel companies, seeking to establish liability based on the companies' contributions to climate change.[230] Such lawsuits can be characterized as "loss and damage" claims insofar as they seek compensation from emitters for climate-related injuries (adaptation costs) on the basis of the emitter's contribution to climate change.[231] The advantage of this approach is that adaptation costs can be more readily calculated based on planned or implemented adaptation measures. As discussed above, State obligations with regards to climate finance, including adaptation finance, are partially rooted in State responsibility for GHG emissions, and thus the provision of funding or resources for adaptation can be viewed as a form of restitution for GHG emissions and the losses and damages attributable to those emissions.

E. Government Procedure, Access to Information, Public Participation, and Access to Justice

The Petition asks the Court for clarification on how climate change should be addressed when interpreting state obligations to ensure access to information, public participation, and access to justice, consistent with duties under the Escazú Agreement and other human rights instruments.[232] There are also a number of questions that implicate government procedure, for example, questions about state obligations related to regulation, monitoring, impact assessment, and contingency planning in the context of climate change.[233] Generally speaking, obligations related to government planning and procedure should be characterized in a way that will promote both public participation and science-based decision-making across policy, administrative, and judicial

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[230] *See, e.g.,* Lliuya v. RWE, *supra* note 228; Asmania et al., v. Holcim, *supra* note 228.

[231] Some UN documents define "loss and damage" as the residual losses from climate change that are not avoided through mitigation and adaptation. *See, e.g., Non-economic Losses in the Context of the Work Programme on Loss and Damage,* Technical Paper FCCC/TP/2013/2 (Oct. 9, 2013), https://unfccc.int/resource/docs/2013/tp/02.pdf. Even under this framing, the costs of adaptation would still qualify as loss and damage, since these are residual economic damages that cannot be avoided through mitigation and adaptation. *See also* Maria Antonia Tigre & Margaretha Wewerinke-Singh, *Beyond the North-South Divide: Litigation's Role in Resolving Climate Change Loss and Damage Claims,* REVIEW OF EUROPEAN, COMPARATIVE & INTERNATIONAL ENVIRONMENTAL LAW (2023) (recognizing that the requested remedies in such cases may include compensation for adaptation costs).

[232] Request for Advisory Opinion at § IV(A)(2.A). *See also* Regional Agreement on Access to Information, Public Participation and Access to Justice in Environmental Matters in Latin America and the Caribbean (Escazú Agreement) (2018), https://www.cepal.org/en/escazuagreement; Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention) (1998), https://unece.org/DAM/env/pp/documents/cep43e.pdf.

[233] Request for Advisory Opinion at § IV(A)(2.A).

contexts. The Court should also recognize State obligations to periodically reassess and revise responses to climate change in light of new scientific evidence.

1. Adaptive Management and Government Decision-making

Climate change and scientific knowledge of climate change are constantly evolving. Thus, in order to effectively respond to climate change-related risks, government decision-makers and planners will need to frequently re-evaluate many different types of planning and regulatory decisions and adjust course in light of new information. The Court should therefore recognize an obligation on the part of States to incorporate adaptive management procedures into government decision-making. In particular, adaptive management procedures should ensure that government decision-making is an iterative process that incorporates: (i) periodic monitoring and review of climate actions as well as planning decisions that may be affected by climate change; (ii) specific mechanisms for assessing the results and efficacy of government decisions in light of new scientific data; and (iii) mechanisms for adjusting course based on such assessments.[234]

Recognizing State obligations to pursue adaptive management in the context of climate change would be consistent with existing legal authorities, including UNFCCC and Paris Agreement provisions related to stocktaking (which recognize State obligations to periodically re-assess and revise GHG mitigation commitments), as well as more general legal obligations related to monitoring, environmental assessment, and contingency planning.[235]

2. Access to Information and Public Participation

The Escazú Agreement provides that each State party "shall ensure the public's right of access to environmental information in its possession… in accordance with the principle of maximum disclosure" and "facilitate access to environmental information for persons or groups in vulnerable situations."[236] States also have an obligation to ensure that competent authorities "generate, collect, publicize, and disseminate environmental information relevant to their functions in a systematic,

[234] For example, in the context of river basin management, a government plan could specify thresholds for conservation measures based on monitored flow levels.

[235] *See* IACtHR Advisory Opinion OC-23/17 at § B.1.c (recognizing state obligations to regulate, supervise and monitor, require and approve environmental impact assessments, and prepare contingency plans, as part of broader obligations to prevent environmental harm).

[236] Escazú Agreement Art. 5.

proactive, timely, regular, accessible, and comprehensive manner."[237] The public also has a right to participate in environmental-decision-making processes, and States must take measures to facilitate public participation, particularly for vulnerable groups and individuals.[238] As this Court and other legal authorities have recognized, these requirements are closely related to and part of the State duties to mitigate environmental harm and prevent transboundary harm.[239]

There are several types of information related to climate change that State authorities should be compiling and disclosing in public documents. These include:

- **GHG Emissions Data:** Consistent with the requirements of the Escazú Agreement, other human rights instruments, and UNFCCC instruments, States should prepare and periodically update GHG emissions inventories that provide a detailed account of GHG sources under their jurisdiction. States should also disclose GHG emissions attributable to specific State actions, such as new policies or administrative approvals, and should provide the public with an opportunity to provide feedback on how and whether to proceed with those actions in light of climate change. For example, GHGs should be routinely disclosed as part of existing environmental impact assessment (EIA) procedures. In addition to data on territorial emissions, States should also provide data on extraction-based emissions (i.e., emissions from fossil fuel production, transportation, and processing, even for fuels that are exported to other jurisdictions).[240] To the extent possible, States should also endeavor to provide information on carbon leakage and consumption-based emissions.
- **GHG Mitigation Measures:** States should carefully track their progress on GHG mitigation and periodically publish reports with detailed information about the nature and scope of GHG reduction measures and the effect that those measures are having on actual emissions. Such reports can be coordinated with the UNFCCC stocktaking process for NDCs. The public should also be given an opportunity to review and provide feedback on the efficacy and adequacy of the State's mitigation measures, and that feedback should also be made available to the public along with information about how government decision-makers have incorporated the feedback into climate policies.
- **Climate impact assessments**: States should conduct periodic assessments of climate impacts, exposure, and vulnerability within their territory in order to help inform adaptation planning as well as discussions related to climate finance and loss and damage. Such assessments should be conducted in close coordination with scientists and affected communities, with ample opportunities for public input.

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[237] *Id.* Art. 6.

[238] *Id.* Arts 2(a), 4(b)

[239] *See* IACtHR Advisory Opinion OC-23/17 at § B.1.c ILC Draft articles on Prevention of Transboundary Harm from Hazardous Activities (2001), Arts. 3-18.

[240] *See Held v. Montana, supra* note 156 (holding that a state law prohibiting analysis and disclosure of GHG emissions from fossil fuel extraction and other activities violated plaintiffs' right to a clean and healthful environment).

- **Adaptation measures:** States should track their progress on adaptation planning and periodically publish reports with detailed information about the actions that they have undertaken to protect people and ecosystems from the harmful effects of climate change. Again, there should be an opportunity for public review and feedback, and the State should be transparent regarding how it has responded to public feedback.

States should provide ample opportunities for public participation when conducting these activities and in other aspects of decision-making on climate change. Public participation can improve the quality of decision-making because decision-makers have more complete information – e.g., citizens can share local environmental and scientific knowledge to help inform climate impact assessments and adaptation decisions.[241] Public participation mechanisms can also be structured to enhance accountability – e.g., by requiring decision-makers to justify decisions in light of public feedback. Participatory mechanisms thus play an important role in science-based decision-making.

3. Access to Justice

As this Court has recognized, States have an obligation to guarantee access to justice in relation to their environmental protection obligations, including opportunities to contest any provision, act, or omission of public authorities that violates or could violate obligations under environmental and human rights law.[242] Thus, States must ensure that individuals and communities can use judicial procedures to challenge decisions related to climate policy.

However, in climate litigation, prospective plaintiffs are sometimes denied access to judicial procedures and remedies on the grounds that they lack standing to pursue claims based on climate change-related injuries. For example, courts may determine that plaintiffs cannot establish a particularized injury on the basis of climate change,[243] or that plaintiffs cannot establish a sufficient

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[241] *See* Victoria Reyes-García, *Local Indicators of Climate Change: The Potential Contribution of Local Knowledge to Climate Research*, 7(1) WILEY INTERDISCIP. REV. CLIM. CHANGE 109 (2016), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5023048/.

[242] IACtHR Advisory Opinion OC-23/17 at ¶ 237.

[243] *See, e.g., Verein KlimaSeniorinnen Schweiz v. Bundesrat*, No. A-2992/2017, https://climatecasechart.com/non-us-case/union-of-swiss-senior-women-for-climate-protection-v-swiss-federal-parliament/; *Armando Ferrão Carvalho and Others v. The European Parliament and the Council,* No. T-330/18, https://climatecasechart.com/non-us-case/armando-ferrao-carvalho-and-others-v-the-european-parliament-and-the-council/; *Citizens' Committee on the Kobe Coal-Fired Power Plant v. Japan* (2018), https://climatecasechart.com/non-us-case/citizens-committee-on-the-kobe-coal-fired-power-plant-v-kobe-steel-ltd-et-al/.

causal nexus between emissions and specific climate change-related injuries.[244] Such dismissals often occur before a full trial or investigation of facts.

In order to guarantee access to justice in the context of climate change, States should ensure that judicial procedures allow plaintiffs adequate opportunities to present scientific evidence in support of standing claims. Some jurisdictions recognize that organizations and groups may file lawsuits on behalf of the public interest, in which case standing can be established based on public harm or endangerment.[245] In other cases, plaintiffs may need to demonstrate that they have experienced a particularized injury (or risk of injury) due to the defendant's conduct or inaction in order to have standing to sue.[246] In such cases, questions of injury and causation are closely intertwined with the merits of the case, such that it may be prudent for courts to evaluate both issues in the same factual investigation. The UN Human Rights Committee recently recognized this very point when it affirmed the admissibility of the Torres Strait islanders' claims in *Daniel Billy et al. v. Australia,* where it noted that "whether the authors' Covenant rights were breached cannot be dissociated from the merits of the case").[247] There are also a number of domestic cases in which courts have found that plaintiffs have standing to enforce individual rights claims on the basis of their unique climate change-related injuries.[248] These decisions can be contrasted to a recent judgment from the European Court of Justice (ECJ) holding that individuals lack standing

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[244] *See, e.g., Washington Environmental Council v. Bellon*, 732 F.3d 1131 (9th Cir. 2013), https://climatecasechart.com/case/washington-environmental-council-v-bellon/; *Native Village of Kivalina v. ExxonMobil Corp.*, 663 F.Supp.2d 863 (N.D. Cal. 2009), https://climatecasechart.com/case/native-village-of-kivalina-v-exxonmobil-corp/.

[245] *See, e.g., Urgenda v. Netherlands, supra* note 134 (recognizing that non-governmental organizations have standing to sue on behalf of the public interest). *See also Nuestros Derechos al Futuro y Media Ambiente Sano et al., v. Mexico*, Amparo No. 204/2021 (First Circuit Collegiate Tribunal, April 7, 2021), https://climatecasechart.com/non-us-case/nuestros-derechos-al-futuro-y-medio-ambiente-sano-et-al-v-mexico-unconstitutionality-of-the-reform-to-the-electric-industry-law/ (recognizing that non-governmental organizations have legal standing to file amparo lawsuits (constitutional challenges) to defend the right to a healthy environment). *Cf. Julia Habana et al. v. Mexico* (Unconstitutionality of the reform to the Electricity Industry Law*),* Amparo No. 210/2021 (Supreme Court of Mexico Dec. 7, 2022), https://climatecasechart.com/non-us-case/julia-habana-et-al-v-mexico-unconstitutionality-of-the-reform-to-the-electricity-industry-law/ (to have standing, individual plaintiffs must show that they have a personal, qualified, current, real and legally relevant interest in the case); *Jóvenes v. Gobierno de México,* Amparo No. 1854/2019 (District Court on Administrative Matters, May 20, 2021), https://climatecasechart.com/non-us-case/youth-v-government-of-mexico/ (to have standing, individual plaintiffs must establish that they are in a situation that differentiates them from the rest of society).

[246] *See, e.g., Jóvenes v. Gobierno de México, supra* note 246; Julia Habana et al. v. Mexico, *supra* note 246.

[247] *Daniel Billy et al. v. Others, supra* note X, at para 7.3

[248] *See, e.g., Held v. Montana, supra* note 156; *Future Generations v. Ministry of* Environment (Colombia)*, supra* note 134.

to challenge European Union climate policies of general application on the basis of climate-related injuries because climate change affects all individuals in one manner or another.[249] If the ECJ's reasoning were extended to other legal systems and rights-based claims, it would preclude essentially all individuals from enforcing fundamental rights in the context of climate change. Thus, the approach taken by the UN Human Rights Committee and other courts is more consistent with human rights law and State obligations to ensure access to justice.

Conclusion

As detailed above, the scientific evidence shows that climate change poses a real and pervasive threat to a broad array of human rights, and that States must undertake ambitious mitigation and adaptation measures in order to prevent and mitigate harm to people and ecosystems. Scientific research can also be used to assess the relative responsibility of different States for climate change and attributable harms, thus informing legal determinations on States' differentiated responsibilities with respect to climate change mitigation, climate finance, and loss and damage. Climate science thus provides evidentiary support for recognizing and characterizing a wide array of State obligations related to the protection of human rights in the context of climate change.

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[249] *Armando Ferrão Carvalho and Others v. The European Parliament and the Council*, *supra* note 244.

Appendix: List of Attachments

Attachment 1:	KATELYN HORNE, MARIA ANTONIA TIGRE, & MICHAEL GERRARD, STATUS REPORT ON PRINCIPLES OF INTERNATIONAL AND HUMAN RIGHTS LAW RELEVANT TO CLIMATE CHANGE (Sabin Center for Climate Change Law, 2023)
Attachment 2:	MICHAEL BURGER & MARIA ANTONIA TIGRE, GLOBAL CLIMATE LITIGATION REPORT: 2023 STATUS REVIEW (Sabin Center for Climate Change Law, Columbia Law School & United Nations Environment Programme, 2023)
Attachment 3:	Michael Burger, Jessica Wentz, & Radley Horton, *The Law and Science of Climate Change Attribution,* 45(1) COLUM. J. ENVTL. L. 57 (2020)
Attachment 4:	WORLD METEOROLOGICAL ORGANIZATION (WMO), STATE OF THE CLIMATE IN LATIN AMERICA AND THE CARIBBEAN 2021 (2022)
Attachment 5:	Stella M. Hartinger et al., *The 2022 South America Report of the Lancet Countdown on Health and Climate Change,* 20 LANCET REGIONAL HEALTH – AMERICAS (2023)
Attachment 6:	Christopher Bataille et al., *Net-zero Deep Decarbonization Pathways in Latin America: Challenges and Opportunities* (Inter-American Development Bank Sept. 2020)
Attachment 7:	Christopher Bataille et al., *Policy Lessons from the Deep Decarbonization Pathways in Latin America and the Caribbean Project: Overall Synthesis and Country Team Perspectives* (2020).

ANEXO 1

2023

Status Report on Principles of International and Human Rights Law Relevant to Climate Change

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Status Report on Principles of International and Human Rights Law Relevant to Climate Change

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April 2023

ABOUT THE SABIN CENTER FOR CLIMATE CHANGE LAW, COLUMBIA LAW SCHOOL

The Sabin Center for Climate Change Law develops legal techniques to fight climate change, trains law students and lawyers in their use, and provides the legal profession and the public with up-to-date resources on key topics in climate law and regulation. It works closely with the scientists at Columbia University's Climate School and with a wide range of governmental, non-governmental and academic organizations.

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NOTE:

The Sabin Center prepared the Status Report for the Pacific Islands Students Fighting Climate Change (PISFCC) and the World's Youth for Climate Justice (WYCJ). The report is part of the Youth Climate Justice Handbook. The Handbook comprises three components: (1) the Summary for Policymakers, (2) the Legal Memorandum, and (3) the Status Report on Principles of International and Human Rights Law Relevant to Climate Change. The Status Report was prepared separately from the other two documents.

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I. INTRODUCTION

1. The United Nations General Assembly has repeatedly discussed and recognized the threats posed by environmental degradation and climate change. On 29 March 2023, the General Assembly adopted Resolution A/77/76, through which it has requested from the International Court of Justice ("**ICJ**" or "**Court**")—the principal judicial organ of the United Nations—an advisory opinion on the legal obligations of States in respect of climate change and the environment.

2. This status report aims to provide high-level guidance on the upcoming proceeding and the legal issues to be analyzed by the Court.[1] In the following sections, this status report will therefore address (i) advisory proceedings before the ICJ, including the Court's jurisdiction and procedure (Section II), and (ii) key legal principles relevant to the request for an advisory opinion, including principles of international environmental law and international human rights law (Section III).

II. ADVISORY PROCEEDINGS BEFORE THE INTERNATIONAL COURT OF JUSTICE

3. The ICJ adjudicates two types of proceedings: contentious cases and advisory proceedings. In a contentious case, the Court hears and adjudicates a legal dispute between two or more States. By contrast, in an advisory proceeding, the Court issues an advisory opinion on a legal question posed by an authorized body.

4. To date, the Court has rendered 28 advisory opinions since its establishment in 1948. Its predecessor, the Permanent Court of International Justice ("**PCIJ**"), delivered 27 advisory opinions between 1922 and 1939. The following sections describe the Court's advisory jurisdiction, the procedure in an advisory proceeding, and the potential impact of an opinion rendered in such a proceeding.

A. The Advisory Jurisdiction of the Court Is Limited

5. The U.N. Charter and the Statute of the Court limit the advisory jurisdiction of the Court. Specifically, the Court may only issue an advisory opinion if two requirements are satisfied: (i) the request for an advisory opinion was submitted by an authorized body competent to submit that request, and (ii) the request is for an opinion on a legal question. In issuing an advisory opinion, the Court must

[1] This status report does not provide a comprehensive analysis, or advocate for or predict particular results. This status report also does not provide legal advice, or establish an attorney-client relationship with any recipient or reader.

determine that both of these requirements are satisfied.[2] As discussed below, both requirements are satisfied in the present case.

6. *First*, the request for an advisory opinion has been submitted by an authorized body with competence to make such a request. In this respect, Article 65(1) of the Statute of the Court states that

> [t]he Court may give an advisory opinion on any legal question at the request of whatever body may be authorized by or in accordance with the Charter of the United Nations to make such a request.[3]

7. Article 96 of the U.N. Charter provides as follows:

> 1. The General Assembly or the Security Council may request the International Court of Justice to give an advisory opinion on any legal question.
>
> 2. Other organs of the United Nations and specialized agencies, which may at any time be so authorized by the General Assembly, may also request advisory opinions of the Court on legal questions arising within the scope of their activities.[4]

8. Article 96(1) thus authorizes both the General Assembly and the Security Council to request an advisory opinion, without specifying that the request "aris[e] within the scope of their activities." Nonetheless, when presented with a request from the General Assembly for an advisory opinion, the Court has considered whether such request falls within the competence of the General Assembly.[5] That competence is, as the Court recognized, extremely broad:

> The Court would observe that Article 10 of the Charter has conferred upon the General Assembly a competence relating to "any questions or any matters" within the scope of the Charter, and that Article 11, paragraph 2, has specifically provided it with competence on "questions relating to the maintenance of international peace and security brought before it by any Member of the United Nations . . .

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[2] *Legal Consequences of the Construction of a Wall in the Occupied Palestinian Territory*, Advisory Opinion, ICJ Reports 2004 (9 July 2004), ¶ 15 ("It is for the Court to satisfy itself that the request for an advisory opinion comes from an organ or agency having competence to make it.").

[3] Statute of the Court, Art. 65(1).

[4] U.N. Charter, Art. 96.

[5] *Legal Consequences of the Construction of a Wall in the Occupied Palestinian Territory*, Advisory Opinion, ICJ Reports 2004 (9 July 2004), ¶ 16 ("Although the above-mentioned provision states that the General Assembly may seek an advisory opinion 'on any legal question,' the Court has sometimes in the past given certain indications as to the relationship between the question the subject of a request for an advisory opinion and the activities of the General Assembly.").

> "and to make recommendations under certain conditions fixed by those Articles.[6]

9. The first jurisdictional requirement is satisfied in the present case. The request has been submitted by the General Assembly, which is authorized to submit such requests. Issues related to climate change and human rights fall within the scope of the U.N. Charter, and relate to the maintenance of international peace and security, as evidenced by the fact that the General Assembly has been seized of these issues on countless occasions.[7] Accordingly, the advisory opinion has been requested by an authorized body, and falls within the competence of that body.

10. *Second*, the authorized body must request an advisory opinion on a legal question. This requirement derives from Article 96 of the U.N. Charter, which authorizes the Court to issue an advisory opinion on a "legal question."[8] This requirement is reiterated in the Statute of the Court[9] and Rules of the Court.[10] In its most recent advisory opinion, the Court assessed the nature of the request as follows:

> In the present proceedings, the first question put to the Court is whether the process of decolonization of Mauritius was lawfully completed having regard to international law when it was granted independence following the separation of the Chagos Archipelago. The second question relates to the consequences arising under international law from the continued administration by the United Kingdom of the Chagos Archipelago. **The Court considers that a request from the General Assembly for an advisory opinion to examine a situation by reference to international law concerns a legal question**.[11] (Emphasis added)

11. In other words, "questions 'framed in terms of law and rais[ing] problems of international law . . . are by their very nature susceptible of a reply based on law.'"[12] Moreover, the Court has repeatedly emphasized that "the fact that a

[6] *Legal Consequences of the Construction of a Wall in the Occupied Palestinian Territory*, Advisory Opinion, ICJ Reports 2004 (9 July 2004), ¶ 17.
[7] *See, e.g.*, U.N. General Assembly Resolution A/76/L.75, 28 July 2022.
[8] U.N. Charter, Art. 96.
[9] Statute of the Court, Art. 65. *See also Legal Consequences of the Separation of the Chagos Archipelago from Mauritius in 1965*, Advisory Opinion, ICJ Reports 2019 (25 February 2019), ¶ 55 ("The Court's jurisdiction to give an advisory opinion is based on Article 65, paragraph 1, of its Statute which provides that '[t]he Court may give an advisory opinion on any legal question at the request of whatever body may be authorized by or in accordance with the Charter of the United Nations to make such a request.'").
[10] Rules of the Court, Art. 102.
[11] *Legal Consequences of the Separation of the Chagos Archipelago from Mauritius in 1965*, Advisory Opinion, ICJ Reports 2019 (25 February 2019), ¶ 58.
[12] *Accordance with International Law of the Unilateral Declaration of Independence in Respect of Kosovo*, Advisory Opinion, ICJ Reports 2010 (22 July 2010), ¶ 25 (citing *Western Sahara*, Advisory Opinion, ICJ Reports 1975 (16 October 1975), p. 18, ¶ 15).

question has political aspects does not suffice to deprive it of its character as a legal question."[13]

12. The present request is framed in terms of international law, and specifically asks the Court about the existence and scope of States' legal obligations under international law. The present request thus appears to satisfy the second jurisdictional requirement for an advisory opinion.

B. The Court Has Discretion

13. Even if the aforementioned jurisdictional requirements are satisfied, the Court retains discretion as to whether or not to issue an advisory opinion. This discretion is enshrined in Article 65(1) of the Statute:

> The Court **may** give an advisory opinion on any legal question at the request of whatever body may be authorized by or in accordance with the Charter of the United Nations to make such a request.[14] (Emphasis added)

14. In addressing its discretion, the Court has emphasized that "[a] reply to a request for an [advisory] opinion should not, in principle, be refused."[15] More specifically:

> It is well settled in the Court's jurisprudence that when a request is made under Article 96 of the Charter by an organ of the United Nations or a specialized agency for an advisory opinion by way of guidance or enlightenment on a question of law, the Court should entertain the request and give its opinion unless there are "compelling reasons" to the contrary.[16]

15. The determination as to whether there are "compelling reasons" to refuse to issue an advisory opinion may require the Court to consider (*inter alia*) (i) whether the requesting organ was interfering in the activities of another United Nations organ, (ii) whether the organ is attempting to secure a resolution to a dispute without the

[13] *Accordance with International Law of the Unilateral Declaration of Independence in Respect of Kosovo*, Advisory Opinion, ICJ Reports 2010 (22 July 2010), ¶ 27.
[14] Statute of the Court, Art. 65(1).
[15] *Reservations to the Convention on the Prevention and Punishment of the Crime of Genocide*, Advisory Opinion, ICJ Reports 1951 (28 May 1951), pp. 15, 19.
[16] *Applicability of Article VI, Section 22, of the Convention on the Privileges and Immunities of the United Nations*, Order, 1989 ICJ Reports (14 June 1989), p. 191. *See also Accordance with International Law of the Unilateral Declaration of Independence in Respect of Kosovo*, Advisory Opinion, ICJ Reports 2010 (22 July 2010), ¶ 30 ("[T]he consistent jurisprudence of the Court has determined that only "compelling reasons" should lead the Court to refuse its opinion in response to a request falling within its jurisdiction") (citing *Judgments of the Administrative Tribunal of the I.L.O. upon Complaints Made against the U.N.E.S.C.O*, Advisory Opinion, ICJ Reports 1956 (23 October 1956), p. 86; *Legal Consequences of the Construction of a Wall in the Occupied Palestinian Territory*, Advisory Opinion, ICJ Reports 2004 (9 July 2004), p. 156, ¶ 44).

consent of the disputing States, or (iii) whether the request concerns matters within the domestic jurisdiction of a State. Notably, however, the ICJ has never exercised its discretion to refuse to issue a requested advisory opinion. Its predecessor, the PCIJ, did so on only one occasion. In the *Status of Eastern Carelia* case, the PCIJ observed that the question concerned an "actual dispute" between two States over territory,[17] and that the request for an advisory opinion thus constituted an attempt to secure a judgment resolving the dispute, without the consent of one of the disputing States.[18] The PCIJ "therefore f[ound] it impossible to give its opinion on a dispute of this kind."[19]

16. Here, the resolution seeking an advisory opinion was adopted by consensus. Nonetheless, any States opposed to the issuance of an advisory opinion may argue that there are compelling reasons for the Court not to issue the requested advisory opinion. For instance, opponents may (i) criticize the motives of States that supported the request in the General Assembly,[20] (ii) assert that any opinion issued by the Court would have no practical effect,[21] or (iii) argue that the Court is not in a position to predict or address the effects of climate change. The Court has previously rejected similar arguments, dismissing as irrelevant the alleged motives of particular States, or speculation about the future impact of an opinion.[22]

C. The Applicable Rules of Procedure

17. The Statute and Rules of the Court establish the procedural rules that apply to advisory proceedings, which are similar to those that apply to contentious cases,

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[17] *Status of Eastern Carelia*, Advisory Opinion, PCIJ Third Ordinary Session (23 July 1923), p. 27.

[18] *See Status of Eastern Carelia*, Advisory Opinion, PCIJ Third Ordinary Session (23 July 1923), p. 28 ("Such consent, however, has never been given by Russia. On the contrary, Russia has, on several occasions, clearly declared that it accepts no intervention by the League of Nations in the dispute with Finland.").

[19] *Status of Eastern Carelia*, Advisory Opinion, PCIJ Third Ordinary Session (23 July 1923), p. 28.

[20] *See, e.g.*, *Accordance with International Law of the Unilateral Declaration of Independence in Respect of Kosovo*, Advisory Opinion, ICJ Reports 2010 (22 July 2010), ¶ 32 ("One argument, advanced by a number of participants in the present proceedings, concerns the motives behind the request. . . . According to those participants, . . . the opinion of the Court was being sought not in order to assist the General Assembly but rather to serve the interests of one State and that the Court should, therefore, decline to respond.").

[21] *See, e.g.*, *Accordance with International Law of the Unilateral Declaration of Independence in Respect of Kosovo*, Advisory Opinion, ICJ Reports 2010 (22 July 2010), ¶ 34 ("It was also suggested by some of those participating in the proceedings that [the request for an advisory opinion] gave no indication of the purpose for which the General Assembly needed the Court's opinion and that there was nothing to indicate that the opinion would have any useful legal effect. This argument cannot be accepted. The Court has consistently made clear that it is for the organ which requests the opinion, and not for the Court, to determine whether it needs the opinion for the proper performance of its functions").

[22] *See, e.g.*, *Accordance with International Law of the Unilateral Declaration of Independence in Respect of Kosovo*, Advisory Opinion, ICJ Reports 2010 (22 July 2010), ¶¶ 32–35.

with certain modifications.[23] In particular, the Statute and Rules of the Court dictate that the advisory proceeding will unfold as follows.

18. Submission of the request. The U.N. Secretary-General[24] must submit to the Court "a written request containing an exact statement of the question upon which an opinion is required, and accompanied by all documents likely to throw light upon the question."[25]

19. Notice of the request. The Court will subsequently provide notice through the Registry, or the permanent administrative secretariat of the Court, which handles all communications to and from the Court. Specifically, "[t]he Registrar shall forthwith give notice of the request for an advisory opinion to all states entitled to appear before the Court."[26]

20. Special notice of deadlines for submissions. The Court will also notify States and international organizations that are "likely to be able to furnish information on the question, that the Court will be prepared to receive, within a time-limit to be fixed by the President, written statements, or to hear, at a public sitting to be held for the purpose, oral statements relating to the question."[27] The States that are entitled to appear before the Court are the States Parties to the Statute of the Court.[28] This direct communication is usually sent to the international organization that submitted the request (i.e., the General Assembly), and the member States thereof (i.e., all General Assembly Member States). Notably, international non-governmental organizations will not have the same rights as intergovernmental organizations; any submission by an international non-governmental organization "is not to be considered as part of the case file," but will instead "be treated as publications readily available"—i.e., as any other document in the public domain.[29]

21. Request for permission to intervene. If a State or international governmental organization did not receive the aforementioned special notice, that State or

[23] *See* Rules of the Court, Art. 102(2) ("The Court shall also be guided by the provisions of the Statute and of these Rules which apply in contentious cases to the extent to which it recognizes them to be applicable. For this purpose, it shall above all consider whether the request for the advisory opinion relates to a legal question actually pending between two or more States."). *See also* ICJ Handbook, p. 84.
[24] In the event that the request was not made by a U.N. organ, the request would be sent by "the chief administrative officer of the body authorized to make the request." *See* Rules of the Court, Art. 104.
[25] ICJ Statute, Art. 65(2).
[26] ICJ Statute, Art. 66(1).
[27] ICJ Statute, Art. 66(2).
[28] ICJ Statute, Art. 35(1) ("The Court shall be open to the states parties to the present Statute."). The Court has made exceptions under particular circumstances. For instance, although Palestine is not considered a State entitled to appear before the Court, the Court determined that Palestine could provide submissions in the case concerning *Legal Consequences of the Construction of a Wall in the Occupied Palestinian Territory*.
[29] Practice Directions of the Court, Practice Direction XII.

organization may request to present a written or oral submission, and the Court will decide upon that request.[30]

22. Written submissions by authorized States and international organizations. As noted above, the President of the Court will establish a deadline for written submissions. The time limits for such submissions are generally shorter than those that apply in contentious proceedings, but the rules allow for flexibility.[31] On average, the Court has provided two months for States to file written submissions (in English or French) on a request for an advisory opinion.[32] However, authorized States and international organizations can request extensions.[33]

23. Comments on written submissions. The Statute of the Court provides that "States and organizations having presented written or oral statements or both shall be permitted to comment on the statements made by other states or organizations in the form, to the extent, and within the time-limits which the Court, or, should it not be sitting, the President, shall decide in each particular case."[34]

24. Oral proceedings. The Court may, and nearly always does, hold an oral proceeding during which authorized States and international organizations may make oral submissions.[35]

25. Delivery of advisory opinion. The Court is required to "deliver its advisory opinions in open court, notice having been given to the Secretary-General and to the representatives of Members of the United Nations, of other states and of international organizations immediately concerned."[36] Members of the Court may append declarations or separate or dissenting opinions to the advisory opinion.

D. The Potential Impact of an Advisory Opinion

26. By their nature, advisory opinions delivered by the Court are not binding. Nonetheless, an advisory opinion may have a significant impact, including because (*inter alia*): (i) the prestige and authority of the Court is attached to its

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[30] *See* ICJ Statute, Art. 66(3) ("Should any such state entitled to appear before the Court have failed to receive the special communication referred to in paragraph 2 of this Article, such state may express a desire to submit a written statement or to be heard; and the Court will decide.").
[31] *See* ICJ Handbook, p. 86.
[32] *See* ICJ Handbook, p. 86.
[33] *See, e.g.*, *Legal Consequences for States of the Continued Presence of South Africa in Namibia (South West Africa) notwithstanding Security Council Resolution 276 (1970)*, Advisory Opinion, ICJ Reports 1971 (21 June 1971); *Legality of the Use by a State of Nuclear Weapons in Armed Conflict*, Advisory Opinion, ICJ Reports 1996 (8 July 1996); *Judgment No. 2867 of the Administrative Tribunal of the International Labour Organization upon a Complaint Filed against the International Fund for Agricultural Development*, Advisory Opinion, ICJ Reports 2012 (1 February 2012).
[34] ICJ Statute, Art. 66(4).
[35] *See* Rules of the Court, Art. 105.
[36] ICJ Statute, Art. 67.

advisory opinions; (ii) the Court's reasoning with respect to the existence and scope of principles of international law is widely viewed as authoritative; (iii) States and other actors may rely on an advisory opinion in the context of domestic or international litigation, or in policy discussions; and (iv) the delivery of an advisory opinion may generate publicity. For these and other reasons, advisory proceedings may prompt or contribute to significant changes and developments in international and/or domestic law and policy.[37]

III. LEGAL PRINCIPLES RELEVANT TO THE REQUEST FOR AN ADVISORY OPINION

27. The request for an advisory opinion in the present case poses the following questions:

> (1) What are the obligations of States under international law to ensure the protection of the climate system and other parts of the environment from anthropogenic emissions of greenhouse gases for States, and for present and future generations;
>
> (2) What are the legal consequences under these obligations for States where they, by their acts and omissions, have caused significant harm to the climate system and other parts of the environment, with respect to:
>
> > (a) States, including, in particular, small island developing States, which, due to their geographical circumstances and level of development, are injured or specially affected by or are particularly vulnerable to the adverse effects of climate change?
> >
> > (b) Peoples and individuals of the present and future generations affected by the adverse effects of climate change?

28. The request thus asks the Court to answer a set of questions about the existence and content of existing international law as it relates to environmental harm.

29. Article 38(1) of the Statute of the Court establishes the sources of international law that the Court is required to apply, and states that:

> The Court, whose function is to decide in accordance with international law such disputes as are submitted to it, shall apply:
>
> (a) international conventions, whether general or particular, establishing rules expressly recognized by the contesting states;

[37] For example, the advisory opinion in the case concerning *Legal Consequences for States of the Continued Presence of South Africa in Namibia* was one of a series of steps that ultimately led to the recognition by South Africa of Namibia's independence.

(b) international custom, as evidence of a general practice accepted as law;

(c) the general principles of law recognized by civilized nations;

(d) subject to the provisions of Article 59, judicial decisions and the teachings of the most highly qualified publicists of the various nations, as subsidiary means for the determination of rules of law.[38]

30. The primary sources of international law that the Court shall apply are:

a. Treaties—i.e., written international agreements concluded between two or more States;[39]

b. Customary international law—i.e., principles established through widespread and consistent State practice and corresponding *opinio juris*; and

c. General principles of law—i.e., basic rules and principles that are common to most jurisdictions.

31. As a subsidiary source, the Court may consider judicial decisions and commentary from preeminent scholars and commentators.

32. In order to answer the questions posed above, the Court will evaluate the foregoing sources to determine what, if any, relevant obligations exist under international law, and the scope of those obligations. This status report is not intended to conduct that exercise, which will require exhaustive study. Instead, the sections that follow identify key relevant principles of international environmental law (Section A), key relevant principles of international human rights law (Section B), and issues of intergenerational equities (Section C).

A. Relevant Principles of International Environmental Law

33. The request for an advisory opinion pertains to a series of principles of international environmental law which are in turn derived from principles of customary international law and treaty law.

1. *Customary International Law*

a. Transboundary Harm

[38] Statute of the Court, Art. 38(1).

[39] Vienna Convention on the Law of Treaties, Art. 2 ("'treaty' means an international agreement concluded between States in written form and governed by international law, whether embodied in a single instrument or in two or more related instruments and whatever its particular designation").

34. Almost none of the contemporary environmental threats to the international community concern one country in isolation; they all have cross-border impacts.[40] The principle of transboundary harm mandates that States ensure that the activities carried out within their jurisdictions do not harm the environment and territory of other States.[41] It applies precisely when harm has occurred in the territory of—or in other places under the jurisdiction of control of—a State other than the State of origin, whether or not the impacted State shares a common border.[42]

35. The International Law Commission's ("**ILC**") Draft Articles on Prevention of Transboundary Harm from Hazardous Activities provide that transboundary harm occurs when the following four elements are present: (i) a physical relationship between the activity concerned and the damage caused; (ii) human causation; (iii) a certain threshold of severity that calls for legal action; and (iv) transboundary movement of the harmful effects. To comply with the principle's mandate, States must (*inter alia*): (i) prevent significant transboundary harm or minimize the risk thereof; (ii) cooperate in good faith to prevent significant transboundary harm or minimize the risk thereof; (iii) take legislative, administrative and other measures to establish monitoring mechanisms; (iv) seek prior authorization for new or changes to activities that can cause transboundary harm; (v) rely on risk assessments of possible transboundary harm, including environmental impact assessment; (vi) timely notify of the risk and assessment, and transmit all relevant information to the States potentially affected; (vii) consult other States impacted on measures to prevent significant transboundary harm or minimize the risk thereof; (viii) exchange relevant information and inform the public likely to be affected; (ix) prepare contingency plans for responding to emergencies; and (x) notify of an emergency of transboundary harm.[43]

36. The transboundary principle can be found in numerous treaty preambles, as well as in the operative text of several treaties. Treaty preambles that include the transboundary principle include the U.N. Framework Convention on Climate Change ("**UNFCCC**"), the 1972 London Convention, the Convention on Long-range Transboundary Air Pollution ("**LRTAP**"), and the 1985 Vienna Convention for the Protection of the Ozone Layer. The principle is also referenced in Article 3 of the Convention on Biological Diversity ("**CBD**") and the United Nations

[40] Jutta Brunnée, *The Responsibility of States for Environmental Harm in a Multinational Context-Problems and Trends*, 34(3) LES CAHIERS DE DROIT 827 (1993).

[41] *See The South China Sea Arbitration (The Republic of Philippines v. The People's Republic of China)*, PCA Case No. 2013-19, Award (12 July 2016), ¶ 941 ("The corpus of international law relating to the environment . . . requires that States 'ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control.'").

[42] ILC Draft articles on Prevention of Transboundary Harm from Hazardous Activities (2001), Art. 2(c).

[43] *Id.*, Arts. 3-18.

Convention on the Law of the Sea ("**UNCLOS**"). Principle 21 of the Stockholm Declaration and Principle 2 of the Rio Declaration explicitly adopted avoiding transboundary harm as a general principle of international law. Principle 2 provides that:

> States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.[44]

(i) Obligation to Exercise Due Diligence

37. The duty to avoid transboundary harm is a due diligence obligation, imposing standards of State conduct.[45] It requires States to protect persons or activities beyond their territories to prevent harmful events and outcomes. The duty to prevent transboundary harm originates from the fact that harm has resulted from such activity, requiring States to exercise due diligence in anticipating, preventing, or mitigating harm.

38. The ICJ confirmed this concept in 1949 in the case concerning *Corfu Channel (United Kingdom v. Albania)* when referring to a State's obligation to not knowingly allow its territory to be used for acts contrary to the rights of other States.[46] Moreover, the arbitral tribunal in the *Trail Smelter Case (United States v. Canada)* concluded that:

> Under the principles of international law, no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence.[47]

39. The advisory opinion on the *Legality of Nuclear Weapons* and the separate opinion of Judge Weeramantry in the case concerning *Gabcikovo-Nagimaros (Hungary/Slovakia)* underline that States are only required to prevent harm caused as a result of an active disposition on or over their territory, which does not include

[44] Report of the United Nations Conference on Environment and Development ("**Rio Declaration**") (1992), Principle 2.
[45] *See The South China Sea Arbitration (The Republic of Philippines v. The People's Republic of China)*, PCA Case No. 2013-19, Award (12 July 2016), ¶ 944.
[46] *Corfu Channel (U.K. v. Alb.)*, ICJ Reports 1949 (9 April 1949).
[47] *Trail Smelter case (United States, Canada)*, Awards, Reports on International Arbitral Awards Vol. III (16 April 1938 and 11 March 1941), pp. 1905–82.

the omission of protective measures.[48] The principle of no harm is breached only when the State of origin has not acted diligently concerning its own activities and those of actors under its jurisdiction.[49]

40. The judgments of the Court in the cases concerning *Pulp Mills on the River Uruguay (Argentina v. Uruguay)* and *Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v. Nicaragua)* provide some, though not entirely consistent, guidance as to the substantive and procedural aspects of the due diligence measures demanded of State actors under the principle.[50]

(ii) Obligation to Conduct an Environmental Impact Assessment

41. An environmental impact assessment ("**EIA**") guides decision-making, including the objectives of: (i) ensuring that environmental effects should be taken into account before decisions are taken to allow activities to be carried out; (ii) providing for the implementation of national environmental impact assessment procedures; and (iii) encouraging reciprocal procedures for notification, information exchange and consultation on activities likely to have significant transboundary effects.[51] The 1991 Espoo Convention requires that parties of origin must notify affected parties of certain proposed activities likely to cause a significant adverse transboundary impact and requires discussion between concerned parties.[52]

42. An EIA is required by international law for environmentally harmful activities which may have transboundary consequences. Principle 17 of the Rio Declaration states that:

> Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a

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[48] *See Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion, ICJ Reports 1996 (8 July 1996), ¶ 29; *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Separate Opinion of Vice-President Weeramantry, ICJ Reports 1997 (25 September 1997).

[49] Rishika Rishabh, *Responsibility v. Sovereignty: Transboundary Environmental Harm*, 4 INT'L J.L. MGMT. & HUMAN 598 (2021).

[50] *See e.g., Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010); *Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v. Nicaragua)* and *Construction of a Road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica)*, Judgment, ICJ Reports 2015 (16 December 2015).

[51] *Environmental Impact Assessment*, Decision 14/25 of the Governing Council of UNEP (17 June 1987); *see also International co-operation in the field of the environment*, U.N. General Assembly Res. 42/184 (11 December 1987).

[52] Espoo Convention on Environmental Impact Assessment in a Transboundary Context (25 February 1991; in force 10 September 1997), Art. 2(1), (4) and (5).

> significant adverse impact on the environment and are subject to a decision of a competent national authority.[53]

43. Principle 17 was adopted in (i) the ICJ's ruling on New Zealand's application to the ICJ concerning the resumption by France of underground nuclear testing (1995),[54] (ii) the case concerning the Gabčíkovo-Nagymaros project (1997),[55] (iii) the dispute between Ireland and the United Kingdom concerning the Mox Plant (2001),[56] and (iv) the *Pulp Mills* case.[57] These judgments and decisions indicate an increasing recognition that international law requires the prior preparation of an EIA before a state engages in or permits an activity that may have severe adverse impacts on the environment.

(iii) Obligation to Notify and Consult in Good Faith

44. The ILC Draft Articles on Prevention of Transboundary Harm adopt establish requirements relating to the dispersal of information to environmental impacts of activities, and provide that where an assessment of risk has taken place and indicates a risk of significant transboundary harm, the State of origin:

> Shall provide the State likely to be affected with timely notification of the risk and the assessment and shall transmit to it the available technical and all other relevant information on which the assessment is based.[58]
>
> States concerned shall enter into consultation, at the request of any of them, with a view to achieving acceptable solutions regarding measures to be adopted in order to prevent significant transboundary harm or at any event to minimize the risk thereof.[59]

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[53] Rio Declaration (1992), Principle 17.

[54] Relevant in this case is the opinion of Judge Weeramantry, who stated that the requirement to carry out an environmental impact assessment was "gathering strength and international acceptance, and has reached the level of general recognition at which the ICJ should take notice of it." *See Request for an Examination of the Sitaution in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France)*, Judge Weeramantry Dissenting Opinion, ICJ Reports 1995 (22 September 1995), p. 344.

[55] The ICJ in this case found a requirement by law that the parties carry out a continuing environmental assessment of the projects' impacts on the environment. Judge Weeramantry's opinion (the majority) stated that "the[] provisions were clearly not restricted to EIA before the project commenced, but also included the concept of monitoring during the continuance of the project." *See Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Vice-President Weeramantry Separate Opinion, ICJ Reports 1997 (25 September 1997), pp. 111–112.

[56] *MOX Plant (Ireland v. United Kingdom)*, Provisional Measures Order, ITLOS Reports 2001 (3 December 2001).

[57] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010).

[58] ILC Draft articles on Prevention of Transboundary Harm from Hazardous Activities (2001), Art. 8(1).

[59] ILC Draft articles on Prevention of Transboundary Harm from Hazardous Activities (2001), Art 9(1).

45. The duty of notification was established in Principle 19 of the Rio Declaration, which requires that States must consult and negotiate with States potentially affected by significant transboundary damage.[60] Such consultations must be conducted promptly and in good faith in order to inform States that may be affected by significant environmental damage due to activities carried out within a State's jurisdiction.[61]

46. The principle of good faith in consultations and negotiations establishes certain restrictions regarding the implementation of such activities. In particular, States must not authorize or execute the activities in question while the parties are consulting and negotiating. The principle of good faith also provides that certain procedural obligations must be followed to ensure proper participation and consultation of parties.

47. The ICJ recognized the principle of good faith in the *Pulp Mills* case, when it indicated that "as long as the procedural mechanism for co-operation between the parties to prevent significant damage to one of them is taking its course, the State initiating the planned activity is obliged not to authorize such work and, *a fortiori*, not to carry it out;" to the contrary, "there would be no point to the co-operation mechanism . . . [and] the negotiations between the parties would no longer have any purpose."[62] Nevertheless, the Court notes that this prohibition does not mean that the activities can only be implemented with the prior consent of any potentially affected States.

48. In the *Lake Lanoux Arbitration (France v. Spain)*, the arbitral tribunal determined that the prior consent of the potentially affected States could not be "established as a custom, even less as a general principle of law."[63] Instead, it could only be understood as a requirement that could be claimed if it were established in a treaty.[64] The ICJ has also underscored that the obligation to negotiate does not entail the duty to reach an agreement. Once the negotiating period has ended, the State can proceed with construction at its own risk.[65] Therefore, this Court considers that, although States must conduct consultation and negotiation procedures as methods of cooperation in the face of possible transboundary harm, States do not necessarily have to reach an agreement, nor is the prior consent of

[60] Rio Declaration (1992), Principle 19.

[61] *State Obligations in Relation to the Environment in the Context of the Protection and Guarantee of the Rights to Life and Personal Integrity: Interpretation and Scope of Articles 4(1) and 5(1) in Relation to Articles 1(1) and 2 of the American Convention on Human Rights*, Advisory Opinion OC-23/17 (Requested by the Republic of Colombia), IACthR (15 November 2017), ¶ 187.

[62] *Cf. Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010), ¶¶ 144, 147.

[63] *Lake Lanoux Arbitration (France v. Spain)*, 12 R.I.A.A. 281; 24 I.L.R. 101 (16 November 1957), p. 25.

[64] *Lake Lanoux Arbitration (France v. Spain)*, 12 R.I.A.A. 281; 24 I.L.R. 101 (16 November 1957).

[65] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010).

the potentially affected States required to initiate the execution of a project, unless this obligation is explicitly established in a treaty applicable to the matter in question.

49. In 2001, the ITLOS prescribed provisional measures ordering Ireland and the United Kingdom to cooperate and, for that purpose, to "enter into consultations forthwith" to exchange further information on the possible consequences for the Irish Sea arising out of the commissioning of the MOX plant.[66]

50. The obligation to consult when there is a risk of a harmful effect on the environment is now widely recognized by customary international law, and the failure to engage in consultation may violate the principles of good faith under international law. The decision in the *Lake Lanoux* arbitration supports this view, which was further elaborated by the ICJ in the *Fisheries Jurisdiction* case, and reflected in the ITLOS' order in the *MOX* case.[67]

b. Precautionary Principle

51. Where there is scientific uncertainty, the precautionary principle provides guidance in the development and application of international environmental law. The precautionary principle aims to reduce or eliminate potential risks; it accomplishes this by (i) banning activities that have or may have negative effects on other countries or areas and (ii) implementing actions aimed at promoting a margin of safety in case of possible threats or damages.[68] The precautionary principle is reflected in Principle 15 of the Rio Declaration, which provides that:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.[69]

52. However, the definition of the principle remains contested and varies by country depending on cultural values and socio-economic interests. Despite these uncertainties, the precautionary principle has been incorporated in many international environmental treaties since 1989 and can be found in more than 60 multilateral treaties covering a myriad of environmental issues such as: the

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[66] *MOX Plant (Ireland v. United Kingdom)*, Provisional Measures Order, ITLOS Reports 2001 (3 December 2001).
[67] *See generally Lake Lanoux Arbitration (France v. Spain)*, 12 R.I.A.A. 281; 24 I.L.R. 101 (16 November 1957); *Fisheries Jurisdiction (United Kingdom v. Iceland)*, Merits, Judgment, ICJ Reports 1974 (25 July 1974); *MOX Plant (Ireland v. United Kingdom)*, Provisional Measures Order, ITLOS Reports 2001 (3 December 2001).
[68] David VanderZwaag , *The Precautionary Approach in Coastal/Ocean Governance: Beacon of Hope, Seas of Confusion and Challenges*, MARINE & ENVIRONMENTAL LAW INSTITUTE (2018).
[69] Rio Declaration (1992), Principle 15.

conservation and the protection of the marine environment;[70] persistent organic pollutants;[71] the protection of the ozone layer;[72] biodiversity conservation;[73] transboundary watercourses;[74] and many others. The UNFCCC incorporates the precautionary principle specifically under Article 3, paragraph 3, reaffirming Principle 15 of the Rio Declaration where it states that:

> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effect. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost..[75]

53. The development of scientific knowledge is essential in implementing the precautionary principle within the framework of the climate regime. For example, the Intergovernmental Panel on Climate Change (IPCC), established by the UNEP and the World Meteorological Organization in 1988, for the purpose of providing scientific guidance on counteracting climate change resulting from the emission of carbon dioxide and other greenhouse gases, publishes periodic reports to justify increased measures to mitigate and adapt to the effects of climate change.

54. International courts and tribunals have been reluctant to accept that the precautionary principle has status as customary international law.[76] The principle

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[70] *See* Convention on the Protection of the Marine Environment of the North-East Atlantic ("OSPAR Convention") (1992); Convention on the Protection of the Marine Environment of the Baltic Sea ("Helsinki Convention") (1992); U.N. Fish Stocks Agreement (1995); London Protocol to the Convention on the Prevention of Pollution by Dumping of Wastes (1996); Cartagena Protocol on Biosafety to the Convention on Biological Diversity (2000); and Stockholm Convention on Persistent Organic Pollutants (2001).

[71] *See* Stockholm Convention on Persistent Organic Pollutants (2001), recognizing the precautionary principle as an objective in its Preamble.

[72] *See* Vienna Convention for the Protection of the Ozone Layer (1985). It does not use the word "precautionary principle," but its preamble instead contains the concept of precautionary measures, stating that, because of the "potentially harmful impact on human health and the environment through modification of the ozone layer," precautionary action must be taken at both the national and international levels. It also points out that precautionary measures should be based on relevant scientific and technical considerations. *See also* Montreal Protocol on Substances that Deplete the Ozone Layer (1987). It does not use the phrase "precautionary principle" either, but defines the obligations of signatories in a manner that reflects the precautionary idea and specific ways of implementing the principle.

[73] *See* Convention on Biological Diversity (1992), where in its preamble it states "[w]here there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat."

[74] *See* Convention of the Protection and Use of Transboundary Watercourses and International Lakes (1992), Art. 2, ¶ 5(a).

[75] UNFCCC (1992), Art. 3(3).

[76] Philippe Sands, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW (2d. ed. 2003), p. 279.

was first raised before the ICJ by New Zealand in 1995, in a request concerning French nuclear testing.[77] New Zealand relied extensively on the precautionary principle, which it described as "a very widely accepted and operative principle of international law," which shifted the burden onto France to prove that the proposed tests would not give rise to environmental damage.[78] Five intervening states (Australia, Micronesia, the Marshall Islands, Samoa, and the Solomon Islands) also invoked the principle. In its order dismissing New Zealand's application, the ICJ noted that its *Nuclear Tests* judgements "dealt exclusively with atmospheric nuclear tests," such that "it is not possible for the Court now to take into consideration questions relating to underground nuclear tests."[79] Although the ICJ did not resolve the question of the status of precautionary principle in international law, the case provided some important insights into the principle. For instance, in his dissenting opinion, Judge Weeramantry acknowledged that the precautionary principle had gradually gained wide support in international environmental law and that with regard to the burden of proof, France was obligated to provide countervailing evidence to that presented by New Zealand; Judge Koroma agreed with this position, stating that France should bear the burden of proof.[80]

55. In *Gabčíkovo-Nagymaros* (*Hungary v. Slovakia*), Hungary argued that its postponement of the dam project was based on the precautionary principle, under which countries had the obligation to prevent possible hazards.[81] Although the ICJ recognized that new developments in international environmental law could be a basis for the performance or non-performance of controversial treaties, it did not

[77] *See generally Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France) Case*, Order, ICJ Reports 1995 (22 September 1995). In the original case, Australia and New Zealand had initiated proceedings based upon France's atmospheric nuclear tests in the South Pacific. Australia claimed that its sovereignty had been violated, and New Zealand claimed that its marine ecosystem and even the atmosphere had been contaminated by radioactive materials. *See Nuclear Tests (Australia v. France)*, Judgment, ICJ Reports 1974 (20 December 1974); *Nuclear Tests (New Zealand v. France)*, Judgment, ICJ Reports 1974 (20 December 1974).
[78] *Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France) Case*, New Zealand's Request for an Examination of the Situation (21 August 1995), pp. 53–54. *See also Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France) Case*, Order, ICJ Reports 1995 (22 September 1995), ¶¶ 5, 34.
[79] *See Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France) Case*, Order, ICJ Reports 1995 (22 September 1995), ¶ 63.
[80] *See Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France) Case*, Dissenting Opinion of Judge Weeramantry, ICJ Reports 1995 (22 September 1995); *Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests (New Zealand v. France) Case*, Dissenting Opinion of Judge Koroma, ICJ Reports 1995 (22 September 1995).
[81] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Judgment, ICJ Reports 1997 (25 September 1997).

take a position on whether countries could use the precautionary principle to justify steps to protect transnational resources; further, the ICJ sidestepped the question of whether the precautionary principle should be part of customary international law.[82]

56. Even though the ICJ acknowledged that the concerns expressed by Hungary were related to an essential interest of the State, the Court found that Hungary had not proved that "a real 'grave' and 'imminent' 'peril' existed in 1989" or that measures taken by Hungary were the only possible response.[83] The ICJ found that there were serious uncertainties concerning future harm to freshwater supplies and biodiversity, but that these "could not, alone, establish the objective existence of a "peril" in the sense of a component element of a state of necessity."[84] This pronouncement, however, was prior to the Rio Declaration.

57. The case concerning *Pulp Mills on the River Uruguay (Argentina v. Uruguay)* reversed the trend within international environmental law of incorporating a broad reading of the precautionary principle. When invoking the principle, tribunals had called for a lower standard of proof of environmental harm or, more radically, argued that the burden of the proof in environmental cases lay with the defendants rather than the plaintiffs.[85] In its judgment, the ICJ rejected both of these readings, leaving only a vaguely defined and weak precautionary principle.[86] Specifically, the ICJ stated that "[w]hile a precautionary approach may be relevant in the interpretation and application of the provisions of the Statute,[[87]] it does not follow that it operates as a reversal of the burden of proof."[88] The ICJ then found that Argentina had failed to meet its burden of proof for all the environmental harms it claimed were likely to occur: "In the absence of convincing evidence that this is not an isolated episode, but rather a more enduring problem, the Court is not in a position to conclude that Uruguay has breached the provision of the 1975 Statute."[89] The ICJ ruled that while Uruguay had violated its

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[82] *See generally Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Judgment, ICJ Reports 1997 (25 September 1997).
[83] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Judgment, ICJ Reports 1997 (25 September 1997), p. 39.
[84] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Judgment, ICJ Reports 1997 (25 September 1997), p. 39.
[85] Daniel Kazhdan, *Precautionary Pulp: Pulp Mills and the Evolving Dispute between International Tribunals over the Reach of the Precautionary Principle,* 38 ECOLOGY L.Q. 527 (2011).
[86] Daniel Kazhdan, *Precautionary Pulp: Pulp Mills and the Evolving Dispute between International Tribunals over the Reach of the Precautionary Principle,* 38 ECOLOGY L.Q. 527 (2011).
[87] *See* Statute of the River Uruguay (Uruguay-Argentina), 1295 UNTS 340 (26 February 1975), Art. 1. This is a treaty that Argentina and Uruguay adopted in order to create a mechanism to rationally use the River Uruguay.
[88] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010), p. 71, ¶ 164.
[89] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010), pp. 90–91, ¶ 228.

procedural obligations, the permit for the pulp mill did not violate any substantive obligations.[90]

58. The *Southern Bluefin Tuna* case,[91] administered by the ITLOS, constitutes a significant example where absence of scientific certainty was used as an excuse for failing to stop a potential harmful activity. In 1999, the ITLOS (under a dispute among Australia, New Zealand, and Japan) requested the parties to immediately refrain from conducting an experimental fishing program ("**EFP**") of southern bluefin tuna ("**SBT**"), which Japan had unilaterally commenced. Australia and New Zealand claimed that under the UNCLOS, parties to a treaty should comply with the precautionary principle when considering an activity that might cause serious or irreparable damage to the environment. and In the event of scientific uncertainties in the links between actions and their consequences, caution should be exercised when making decisions or taking actions that could affect the environment. In addition, Australia and New Zealand demanded that Japan fish SBT in compliance with the precautionary principle. Japan, on the other hand, questioned whether the precautionary principle was actually part of customary international law.[92]

59. The tribunal adopted its order in the face of scientific uncertainties. Particularly, the tribunal held that the parties to the treaty should act prudently to ensure that effective conservation measures were taken in order to prevent serious harm to the SBT stock. In its order, the ITLOS tribunal does not expressly refer to the precautionary approach, but it is apparent that it was applied.[93] Ultimately, however, the order was not sufficient to cement the precautionary principle's status in customary international law.

60. In the *Mixed Oxide Fuel* (*MOX) Plant* case, the ITLOS clarified the extent and limits in the use of the precautionary approach. ITLOS clarified that delineating any limitations of the precautionary principle aids in reducing its overuse, and therefore, any potential for diminished legitimacy. The *MOX Plant* case concerned hazardous waste activities and was a dispute involving marine pollution between the United Kingdom and Ireland, in which , amongst other provisional measures, Ireland requested that the ITLOS stop the United Kingdom from releasing the MOX plant's radioactive waste into the Irish Sea. In its order, the ITLOS emphasized the requirement to indicate the seriousness of the potential harm to the marine environment. In this case, Ireland had failed to meet this necessary

[90] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010).
[91] *Southern Bluefin Tuna (New Zealand v. France; Australia v. Japan)*, Provisional Measures, Order, ITLOS Case No. 3 (1999), 38 ILM 1624, ICGJ 337 (ITLOS 1999) (27 August 1999).
[92] *Southern Bluefin Tuna (New Zealand v. France; Australia v. Japan)*, Provisional Measures, Order, ITLOS Case No. 3 (1999), 38 ILM 1624, ICGJ 337 (ITLOS 1999) (27 August 1999).
[93] *Southern Bluefin Tuna (New Zealand v. France; Australia v. Japan)*, Provisional Measures, Order, ITLOS Case No. 3 (1999), 38 ILM 1624, ICGJ 337 (ITLOS 1999) (27 August 1999).

threshold in demonstrating the urgency and seriousness of the potential harm. The position of the ITLOS under this circumstance aligned with a narrow and stringent approach, applying the precautionary principle following the interpretation contained in the Montreal Protocol's Principle 15.[94] The principle indicates that in order to invoke the precautionary approach, the harm to be prevented cannot be general, but has to be identifiable and clear. Furthermore, the threat must pose serious or irreversible damage to the environment.[95]

61. Although the ITLOS rejected Ireland's request for provisional measures, it assigned the burden of proof in environmental hazard cases to the country taking the actions that might cause the hazards (i.e., the United Kingdom). In other words, the country must prove that its actions were harmless or the precautionary principle would apply.

62. The precautionary approach is also present in the 2011 Seabed Disputes Chamber Advisory Opinion on the Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area[96] on seabed mining activities. In the Advisory Opinion, the Chamber supported a proactive and precautionary approach to seabed mining. When addressing the question whether States that sponsor mining operators may carry different responsibilities and potential liability in case of environmental harm, the Chamber stated that the paramount importance of the marine environment for humanity transcends the economic differences of States. As such, the responsibilities and liability of sponsoring States apply equally to all States, whether developing or developed, and to find otherwise "would jeopardize uniform application of the highest standards of protection of the marine environment, the safe development of activities in the Area and protection of the common heritage of mankind."[97]

c. Duty to Cooperate

63. International cooperation is at the core of effective environmental policies and represents one of the foundations of international law.[98] The duty to cooperate is not only a well-established general principle of international law, but also one of

[94] *MOX Plant (Ireland v. United Kingdom)*, Provisional Measures Order, ITLOS Reports 2001 (3 December 2001).
[95] Yoona Cho, *Precautionary Principle in the International Tribunal for the Law of the Sea,* 10(1) SUSTAINABLE DEVELOPMENT LAW & POLICY 64.
[96] *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area,* Advisory Opinion, Seabed Disputes Chamber, Case No. 17, ITLOS Reports 2011 (1 February 2011).
[97] *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area,* Advisory Opinion, Seabed Disputes Chamber, Case No. 17, ITLOS Reports 2011 (1 February 2011), p. 54.
[98] Christina Leb, *Implementation of the general duty to cooperate*, in RESEARCH HANDBOOK ON INTERNATIONAL WATER LAW (Stephen C. McCaffrey, et al. eds., 2019), p. 96. Maria Antonia Tigre, PRINCÍPIO DA COOPERAÇÃO, PRINCIPIOS DE DERECHO AMBIENTAL Y AGENDA 2030 (Y. Aguila et. al., eds., 2019).

the most significant norms of contemporary international enviornmental law.[99] It is affirmed in virtually all international environmental agreements of bilateral and regional application, international instruments, as well as the jurisprudence of courts and tribunals, treaty bodies, and other international institutions.[100] The cooperation principle has a relatively long history and can be seen as the backbone for the peaceful relations between nation States, and relates, in general terms, to the implementation of a treaty's objectives or to specific commitments under a treaty.[101] Cooperation is especially relevant to combating global problems such as climate change, which requires joint efforts and is a logical consequence of the interdependency of countries.[102] The duty to cooperate has been invoked, among other things, in relation to the environment, human rights, development, and dispute settlement.

64. Over the past century, the duty to cooperate has transformed from a "law of coexistence" to a "law of cooperation."[103] The previous connotation was centered on rules of abstention aimed at identifying limits to state sovereignty. Moreover, it was linked to the obligation to refrain from interfering in the sovereignty sphere of others (*sic utere tuo alienum non laedas*).[104]

65. The set of principles and rules included in the Charter of the United Nations[105] is commonly considered one of the vital treaty sources from which this general principle can be derived. The Charter reflects the agreement of its now 193 Member States in the legally binding rules governing their conduct. In addition to its mandate to maintain international peace and security, the U.N. has as its objective the achievement of "international co-operation in solving international problems of an economic, social, cultural or humanitarian character, and in promoting and encouraging respect for human rights and for fundamental

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[99] Christina Leb, *One step at time: International law and the duty cooperate in the management of shared water resources*, 40 WATER INT'L 21, 23 (2015).

[100] Philippe Sands, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW (1995), pp. 190–194. *See also* Co-operation in the Field of the Environment Concerning Natural Resources Shared by Two or More States, Draft Decision ("**UNEP Draft Principles**") (1978). *See also, e.g.*, *The South China Sea Arbitration (The Republic of Philippines v. The People's Republic of China)*, PCA Case No. 2013-19, Award (12 July 2016), ¶ 984 ("Article 197 of the [U.N.] Convention [on the Law of the Sea] requires States to cooperate on a regional basis to formulate standards and practices for the protection and preservation of the marine environment.").

[101] Patricia Wouters, *Dynamic cooperation in International Law and the Shadow of State Sovereignty in the Context of Transboundary Waters*, 3 ENV. LIABILITY 88 (2013).

[102] Christina Leb, COOPERATION IN THE LAW OF TRANSBOUNDARY WATER RESOURCES (James Crawford & John S. Bell eds., 2013).

[103] Erik Franckx & Marco Benatar, *The "Duty" to Co-Operate for States Bordering Enclosed or Semi-Enclosed Seas*, 31 CHINESE (TAIWAN) YB INT'L L & AFF 66 (2013).

[104] Erik Franckx & Marco Benatar, *The "Duty" to Co-Operate for States Bordering Enclosed or Semi-Enclosed Seas*, 31 CHINESE (TAIWAN) YB INT'L L & AFF 67 (2013).

[105] *See generally*, U.N. Charter (1945).

freedoms for all without distinction as to race, sex, language, or religion."[106] The U.N. system generally provides examples that illustrate the role of international law in the iterative process of cooperation. The U.N. was established based on an international treaty, with a mandate to maintain international peace and security and promote international cooperation.[107] The Charter establishing the U.N. is an outcome of State cooperation.

66. In the field of international environmental law, the recognition that State cooperation was required for the sustainable management of the natural environment and any related issues led to a number of treaties on international cooperation and joint action, most notably those adopted in the context of the 1992 U.N. Conference on Environment and Development in Rio,[108] including the Convention on Biological Diversity,[109] and the U.N. Framework Convention on Climate Change.[110] These conventions contain rules on settling disputes and establish financial mechanisms to assist those countries that do not have the necessary means to comply with the obligations set out in the conventions.

67. The cooperation principle is particularly significant in environmental law contexts where States must protect the natural environment for a common or shared resource.[111] In this specific context, the Charter of Economic Rights and Duties of States provides in Article 3 that: "In the exploitation of natural resources shared by two or more countries, each State must cooperate on the basis of a system of information and prior consultations in order to achieve the optimum use of such resources without causing damage to the legitimate interest of others."[112] The duty to cooperate then becomes particularly relevant when States (i) expect to derive benefits that would otherwise be unachievable, and (ii) need to seek engagement and collaboration with States that are in a position to assist them in order to realize additional gains.

68. A clear example of the necessity of State cooperation is the fight against climate change and its biggest cause: burning fossil fuels, which contributes to the climate crisis by producing large quantities of greenhouse gasses that remain trapped in the atmosphere. The results of global warming are rising sea levels, melting ice caps, and biodiversity loss. Climate change threatens the lives of all people

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[106] U.N. Charter (1945), Art. 1(3).
[107] U.N. Charter (1945), Art. 1.
[108] *See generally* Rio Declaration (1992).
[109] *See generally* Convention on Biological Diversity ("**CBD**") (1992).
[110] *See generally* U.N. Framework Convention on Climate Change ("**UNFCCC**") (1992).
[111] *See* Charter of Economic Rights and Duties of States (1974), Art. 3. This is also underlined in the Advisory Opinion OC-23/17 (15 November 2017) requested by the Republic of Colombia to the Interamerican Court of Human Rights.
[112] U.N. General Assembly, Resolution 3281 (XXIX): Charter of Economic Rights and Duties of States (12 December 1974), Art. 3.

worldwide since access to food, water, and shelter are collectively dependent on biodiversity and healthy ecosystems.[113]

69. In the international climate change regime, cooperation is referred to in all three of the principal governing instruments. The 1992 UNFCCC refers to cooperation in several provisions, including its Preamble as well as Articles 3, 4, 5, 6, 7, and 9.[114] The 1997 Kyoto Protocol references international cooperation in Articles 2, 10, and 13,[115] and the 2015 Paris Agreement refers to international cooperation in its Preamble and Articles 6, 7, 8, 10, 11, 12, and 14.[116] Beyond the broad and abstract appeal to cooperation, these instruments also give real meaning to the duty: the UNFCCC, for example, provides that developed countries should take the lead in combating climate change by facilitating capacity building, offering financial support and transferring technology to developing countries;[117] the Paris Agreement affirms that the nationally determined contributions need to rely on international cooperation to be effective, and that States need to be as ambitious as they can both in reducing their emissions and in supporting other States to do that.[118] Apart from mitigation goals, it also foresees a role for cooperation in strengthening national adaptation efforts.[119] Beyond the pursuit of more equitable burden-sharing, cooperation has other functions under the climate change regime. Indeed, Article 12 of the Paris Agreement provides for cooperative efforts around climate change education, awareness, public participation, and public access to information.[120]

70. As is evident from its provision in these instruments, cooperation between States and other actors should play a critical and multidimensional role in tackling the various challenges presented by climate change.[121] The UNFCCC framework provides an example of how international law can also be used to support or strengthen the role of relatively "weaker" States in the process of international cooperation.[122] In fact, not all States have the resources to take the necessary measures to mitigate or adapt to the effects of climate change, while other States have the resources to do more in the fight against this common global challenge.

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113 World's Youth for Climate Justice, *Human rights in the face of the climate crisis: a youth-led initiative to bring climate justice to the International Court of Justice* (2d. ed. 2022).
114 UNFCCC (1992), Preamble, Arts. 3–7, 9.
115 Kyoto Protocol to the United Nations Framework Convention on Climate Change ("**Kyoto Protocol**") (1998), Arts. 2, 10, 13.
116 Paris Agreement (2015), Preamble, Arts. 6–8, 10–12, 14.
117 UNFCCC (1992), Art. 3(1).
118 Paris Agreement (2015), Art. 6, 6(2).
119 Paris Agreement (2015), Art. 7.
120 Paris Agreement (2015), Art. 12.
121 Jason Rudall, *The Obligation to Cooperate in the Fight against Climate Change*, 23 INTERNATIONAL COMMUNITY LAW REVIEW 184 (2021).
122 *See generally* UNFCCC (1992).

Cooperation can help bridge this gap, calling on more developed countries to take the lead in combating climate change and its harmful effects, including through providing technical and financial assistance to developing countries to meet the costs of adaptation.[123]

71. The general obligation to cooperate has also been translated into more specific commitments through techniques designed to ensure information sharing. These specific commitments include rules on environmental impact assessments; rules ensuring that neighboring states receive necessary information (requiring information exchange, consultation, and notification); the provision of emergency information; and transboundary enforcement of environmental standards. [124]

72. The extent to which these commitments are interrelated is reflected, for example, in Principle 7 of the 1978 UNEP Draft Principles, which states that: "Exchange of information, notification, consultation and other forms of cooperation regarding shared natural resources are carried out on the basis of the principle of good faith and in the spirit of good neighborliness."[125]

73. These procedural obligations arising under the duty to cooperate should be viewed as independent from, and complementary to, other fundamental environmental principles, such as the no harm principle and the precautionary principle. They can be useful to inform the due diligence obligations of States once there is "risk of significant harm," and can come into play where there is a transboundary "adverse effect." But violating each of these obligations can give rise to international State responsibility, due to their independent nature.[126]

74. The ICJ has further clarified the independence nature of procedural obligations. For example, in the *Pulp Mills case*, the Court recognized that States' "procedural" obligations have an independent existence and can be violated regardless of any violation of their "substantive" obligations.[127] Some authors have noted that this approach shifts the emphasis from a "'negative' duty to avoid harm to a 'positive' duty" to cooperate, requiring States to take concrete steps to protect a shared resource even if no significant harm is caused or is likely to be caused.[128]

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[123] Developed States committed to approximately 100 billion dollars per year of financial assistance in accordance with the principle of common but differentiated responsibilities. *See, e.g.,* UNFCCC, *Decision of the Contracting Parties*, FCCC/CP/2015/10/Add.1 (12 December 2015), ¶ 54.
[124] Maria Antonia Tigre, PRINCÍPIO DA COOPERAÇÃO, PRINCIPIOS DE DERECHO AMBIENTAL Y AGENDA 2030 (Y. Aguila et. al., eds., 2019).
[125] UNEP Draft Principles (1978), Art. 7.
[126] Tamar Meshel, *Unmasking the Substance behind the Process: Why the Duty to Cooperate in International Water Law is Really a Substantive Principle*, 47 DENV. J. INT'L L. & POL'Y 29 (2018).
[127] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Judgment, ICJ Reports 2010 (20 April 2010).
[128] Jutta Brunnée, *Procedure and Substance in International Environmental Law: Confused at a Higher Level?*, 5(6) ESIL (June 2016).

d. Principle of Solidarity

75. Under the principle of solidarity, States assist other States without expectations of reciprocity, to "achieve a shared goal or to recover from a critical situation."[129] Therefore, solidarity may refer to the practice of States in response to dangers or events (negative solidarity) or to the creation of joint rights and obligations (positive solidarity).[130] According to the U.N. General Assembly, solidarity is a "fundamental value, by virtue of which global challenges must be managed in a way that distributes costs and burdens fairly, in accordance with basic principles of equity and social justice, and ensures that those who suffer or benefit the least receive help from those who benefit the most."[131]

76. The principle of solidarity is recognized in treaty law and other international instruments,[132] and is in different stages of development in the branches of international law in which it is present (including international human rights and environmental law).[133] In international environmental law, "solidarity is instrumental in achieving common objectives through differentiated obligations."[134] Moreover, "solidarity rights" emerging from the dynamics of interdependence among States and decolonization are increasingly being discussed and recognized, such as the rights to development, peace, and a healthy environment.[135]

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[129] Danio Campanelli, *Principle of Solidarity*, in MAX PLANCK ENCYCLOPEDIAS OF INTERNATIONAL LAW (2018).

[130] Karel Wellens, *Revisiting Solidarity as a (Re-)Emerging Constitutional Principle: Some Further Reflections*, in *Solidarity: A Structural Principle of International Law*, 213 BEITRÄGE ZUM AUSLÄNDISCHEN ÖFFENTLICHEN RECHT UND VÖLKERRECHT 4 (2010).

[131] *See*, *inter alia*, U.N. General Assembly, *Resolution on the Promotion of a democratic and equitable international order*, A/RES/59/193 (18 March 2005) and Resolution A/RES/59/204 (23 March 2004).

[132] For example, Article 3(b) of the 1994 United Nations Convention to Combat Desertification (UNCCD), recognizes that "the Parties should, in a spirit of international solidarity and partnership, improve cooperation and coordination at subregional, regional and international levels, and better focus financial, human, organizational and technical resources where they are needed." Moreover, the U.N. Millenium Declaration (8 September 2000), adopted by the U.N. General Assembly, stipulates that "[s]olidarity. Global challenges must be managed in a way that distributes the costs and burdens fairly in accordance with basic principles of equity and social justice. Those who suffer or who benefit least deserve help from those who benefit most."

[133] Karel Wellens, *Revisiting Solidarity as a (Re-)Emerging Constitutional Principle: Some Further Reflections*, in *Solidarity: A Structural Principle of International Law*, 213 BEITRÄGE ZUM AUSLÄNDISCHEN ÖFFENTLICHEN RECHT UND VÖLKERRECHT 4 (2010).

[134] Karel Wellens, *Revisiting Solidarity as a (Re-)Emerging Constitutional Principle: Some Further Reflections*, in *Solidarity: A Structural Principle of International Law*, 213 BEITRÄGE ZUM AUSLÄNDISCHEN ÖFFENTLICHEN RECHT UND VÖLKERRECHT 13 (2010).

[135] Petra Minnerop, Naomi Roht-Arriaza, & Sara C Aminzadeh, *Solidarity Rights (Development, Peace, Environment, Humanitarian Assistance*, in MAX PLANCK ENCYCLOPEDIAS OF INTERNATIONAL LAW (2018).

77. Solidarity is a cross-cutting principle of international climate change law.[136] Article 3.2 of the UNFCCC stipulates that "the specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, and of those Parties, especially developing country Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration."[137] According to Theresa Thorp, this reflects a notion of distributive fairness, that encompasses "the debt relationship that binds those with assets (active solidarity) with those who suffer (passive solidarity)."[138] Indeed, solidarity as enshrined in article 3.2 of the UNFCCC is a central *lex specialis* principle of climate change law.[139] Solidarity also justifies financial commitments made by developed States to developing and least developed States in the context of climate change,[140] to aid mitigation and adaptation measures,[141] as well as addressing loss and damage.[142]

78. In the context of climate change law, solidarity (together with the principles of equity, cooperation, and sustainable development) also serves as basis for other relevant principles of international environmental law, such as the principle of intergenerational equity, and common but differentiated responsibilities and respective capabilities.[143] Consequently, those who have benefited the most from the causes of anthropogenic climate change are expected to aid those that have benefited the least, or are disproportionately affected from it, without expectations of reciprocity. As such, developed countries are bound to cover more costs and burdens than those imposed on developing countries. At the same time, present generations who benefit from greenhouse gas ("**GHG**") emissions are asked to make important sacrifices in benefit of generations to come.

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[136] Theresa Thorp, *Climate Justice: A Constitutional Approach to Unify the Lex Specialis Principles of International Climate Law*, 8(3) UTRECHT LAW REVIEW 7–37 (2012).

[137] UNFCCC (1992), Art. 3.2.

[138] Theresa Thorp, *Climate Justice: A Constitutional Approach to Unify the Lex Specialis Principles of International Climate Law*, UTRECHT LAW REVIEW, 8(3) UTRECHT LAW REVIEW 7–37 (2012).

[139] Ibid.

[140] UNHRC, *Report of the Independent Expert on human rights and international solidarity, International solidarity and climate change*, A/HRC/44/44 (1 April 2020).

[141] Paris Agreement, Arts. 2(1)(c), 4(4), 9, and 10.

[142] *See* UNFCCC, *Funding arrangements for responding to loss and damage associated with the adverse effects of climate change, including a focus on addressing loss and damage*, Decision -CP.27 -/CMA.4 (20 November 2022), proposed under agenda item 8(f) of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its fourth session; *see also* UNFCCC, *Santiago network for averting, minimizing and addressing loss and damage under the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts*, Decision -/CMA.4 (19 November 2022), proposed under agenda item 7 of the Conference of the Parties at its twenty-seventh session.

[143] *See* Angela Williams, *Solidarity, Justice and Climate Change Law*, 10 MELBOURNE J. INT. LAW 493–508, 503 (2009).

e. Principle of Common, But Differentiated Responsibilities and Respective Capabilities

79. The principle of common but differentiated responsibilities and respective capabilities (hereinafter "**CBDR**") is a cornerstone of international environmental law. It originates from the general principle of international equity. As such, the CBDR recognizes "that the special needs of developing countries must be taken into account in the development, application and interpretation of rules of international environmental law."[144] As its name suggests, CBDR comprises two distinct elements, namely that: (i) States have a common responsibility to protect the environment, and (ii) owing to their contribution to an environmental problem and degree of development, States have differentiated responsibilities and abilities to respond to an environmental threat.[145] In practice, the CBDR principle implies that States must comply with their common obligations to protect the environment, but in a differentiated manner which will be determined based on the State's contribution to an environmental problem and its ability to respond to such a problem.

80. The CBDR is recognized in various international instruments pertaining to the protection of the environment,[146] including the UFCCC, the Kyoto Protocol, and the Paris Agreement. As a general principle of the climate change legal regime, Article 3(1) of the UNFCCC provides that States should "protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof."[147]

81. Most notably, the climate change regime sets out operative criteria to implement such a principle in the compliance with the international obligations pertaining to the protection of the climate system, establishing a sliding scale of State parties and differentiated obligations deriving from such categorization.[148] In this sense, Article 4 of the UNFCCC provides for common and differentiated obligations.[149] In general, all States party to such a Convention have a duty to cooperate in

[144] Philippe Sands and Jacqueline Peel, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW (3d ed. 2012), p. 233.
[145] Ibid.
[146] See, *inter alia*, Declaration of the United Nations Conference on the Human Environment (16 June 1972); Rio Declaration (1992); United Nations Convention on the Law of the Sea (10 December 1982); UNFCCC (1992); Kyoto Protocol (1997); and Paris Agreement (2015).
[147] UNFCCC (1992), Art. 3(1).
[148] *See* UNFCCC, *Annex I: Developed States or Those in Transition to a Market Economy*; *see also* UNFCCC, *Non-Annex I: Developing States and Least Developed Countries*.
[149] UNFCCC (1992), Art. 4.

preventing and addressing climate change through mitigation and adaptation measures. However, developed States who have also contributed the most to climate change (Annex I) must take the lead in advancing mitigation to limit GHG emissions as well as adaptation measures. This logic is also replicated in the Kyoto Protocol, which introduced novel obligations for Annex I State Parties, but did not "introduce any new commitments for Parties not included in Annex I."[150] The Paris Agreement reaffirmed this principle as a bedrock of climate change law, setting out in its Article 2.2 that the treaty must be implemented "to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."[151] However, the Paris Agreement no longer divides countries into two distinct categories. For example, in applying the CBDR principle, the Paris Agreement recognizes that developed country Parties "should continue taking the lead by undertaking economy-wide absolute emission reduction targets," developing country Parties "should continue enhancing their mitigation efforts," and "least developed countries and small island developing States may prepare and communicate strategies, plans and actions for low greenhouse gas emissions development reflecting their special circumstances."[152]

82. When referring to the common responsibility derived from each State's contribution to the harm caused by climate change, the Committee on the Rights of the Child ("**CRC Committee**"), found in *Sacchi et al vs. Argentina*, that "in accordance with the principle of common but differentiated responsibility…the collective nature of the causation of climate change does not absolve the State party of its individual responsibility that may derive from the harm that the emissions originating within its territory may cause to children, whatever their location."[153] The U.N. Special Rapporteur on Human Rights and the Environment has also referred to the CBDR principle, stating that "wealthy States must contribute their fair share towards the costs of mitigation and adaptation in low income countries," through grants and not loans, given that basic principles of justice are violated when poor countries are forced to pay for "the costs of responding to climate change when wealthy countries caused the problem."[154]

83. The Inter-American Commission on Human Rights, in its Resolution on the Climate Emergency, has also highlighted that, under the CBDR principle, "those

[150] Kyoto Protocol (1997), Art. 10.
[151] Paris Agreement (2015), Art. 2(2).
[152] Paris Agreement (2015), Art. 4.
[153] U.N. Committee on the Rights of the Child, *Decision adopted by the Committee under the Optional protocol to the Convention on the Rights of the Child on a communications procedure, concerning communication No. 104/2019* (S*acchi et al. v. Argentina*), CRC/C/88/D/104/2019 (22 September 2021), ¶ 10.10.
[154] UNHRC, *Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment*, A/74/161 (2019), ¶¶ 26 and 68.

States that have greater financial capacity must provide the guarantees to provide greater technical and logistical capacity to the States that have a greater degree of impact on climate change, as well as less financial and infrastructure capacity to face the climate emergency."[155] In this sense, the principle interacts with other relevant norms of international law, such as the principle of cooperation, under which "States that are in a position to do so should contribute to covering the costs of mitigation and adaptation of States prevented from doing so, in accordance with the principle of common but differentiated responsibilities."[156] Additionally, the Commission emphasized that human rights obligations "should not be neglected because of the multi-causal nature of the climate crisis, as all States have common but differentiated obligations in the context of climate action."[157]

f. Equity Under International Environmental Law

84. As a general principle of public international law, equity allows the international community to take into account considerations of justice and fairness in the establishment, operation or application of a rule of law.[158] On this matter, the ICJ has recognized that "the legal concept of equity is a general principle directly applicable as law" which demands from the Court interpreting the relevant rules of international law to achieve an equitable solution[159] derived from the applicable law.[160] Therefore, equity plays a role as an interpretative method for "infusing elements of reasonableness and 'individualized' justice whenever the applicable law leaves a margin of discretion to the court."[161]

85. Equity is generally present—both explicitly and implicitly—in treaties and declarations pertaining to the protection of the environment or its elements, which treaties refer to (i) the equitable use of environmental resources, (ii) the protection of future generations, and (iii) sustainable development.[162] For example, the Rio

[155] Inter-American Commission on Human Rights, *Climate Emergency: Scope of Inter-American Human Rights Obligations*, Resolution No. 3/2 (2021), Point I.7.
[156] Ibid, Point II.11.
[157] Ibid, Point II.15.
[158] Philippe Sands and Jacqueline Peel, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW (3d ed. 2012), p. 119.
[159] *See North Sea Continental Shelf Cases (Federal Republic of Germany/Denmark; Federal Republic of Germany/Netherlands)*, Judgment, ICJ Reports 1969 (20 February 1969), ¶ 71; *Factory at Chorzow (Germany v. Poland)*, 1927 PCIJ (ser. A), No. 9 (26 July 1927), ¶ 82.
[160] *Fisheries Jurisdiction (United Kingdom v. Iceland)*, Merits, Judgment, ICJ Reports 1974 (25 July 1974), ¶¶ 69 and 78.
[161] Francesco Francioni, *Equity in International Law*, in MAX PLANCK ENCYCLOPEDIAS OF INTERNATIONAL LAW (2020), ¶ 7. *See also Frontier Dispute (Burkina Faso v. Mali)*, Judgment, ICJ Reports 1986 (22 December 1986), ¶ 28.
[162] *See, e.g.*, UNFCCC (1992), Art. 3; Paris Agreement (2015), preamble & Arts. 2.2 & 4; Convention on Biological Diversity (22 May 1992), preamble; Declaration of the United Nations Conference on the Human Environment (1972), Principles 1 & 12; Rio Declaration (1992), Principles 6 and 3; Johannesburg Declaration on Sustainable Development (2022), ¶ 24.

Declaration provides that "the right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations."[163] Most notably, the principle of common but differentiated responsibilities and respective capabilities is considered an operationalization of general equity in international environmental law, because it acknowledges factual differences between States which require differentiated approaches in the compliance of international obligations.[164]

86. Several scholars have highlighted the centrality of equity in addressing climate change through the law, while also showcasing the political tensions that arise when discussing issues of justice and fairness in the context of the climate crisis.[165] Article 3(1) of the UNFCCC establishes that State Parties should "protect the climate system for the benefit of present and future generations of humankind, based on equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof."[166] Therefore, the Framework Convention includes considerations of justice and fairness in the application of its provisions, by encouraging developed States to take the lead in climate action and acknowledging the importance of the disproportionate impacts of climate change in developing States.

87. Moreover, the Paris Agreement shall "be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."[167] Therefore, GHG emissions should be limited to achieve a long-term temperature goal, on the "basis of equity, and in the context of sustainable development and efforts to eradicate poverty."[168]

88. It must be highlighted that equity is not only central in international environmental law but is also a principle present in national climate change policies, especially as it relates to equality and non-discrimination in international

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163 Rio Declaration (1992), Principle 3.

164 U.N. Secretary General, *Gaps in international environmental law and environment-related instruments: towards a global pact for the environment*, A/73/419 (30 November 2018), ¶ 21.

165 *See, e.g.*, ILA, *Report of the ILA's Committee on Legal Principles Relating to Climate Change* (2014), Draft Art. 4; Chukwumerije Okereke, *Climate Justice and the international regime*, 1(3) WIREs CLIMATE CHANGE 462 (8 June 2010); Henry Shue, *Global Environment and International Inequality*, INTERNATIONAL AFFAIRS (1999); Eric Neumayer, *In Defence of Historical Accountability for Greenhouse Gas Emissions*, ECOLOGICAL ECONOMICS, No. 33 (2000); Theresa Thorp, *Climate Justice: A Constitutional Approach to Unify the Lex Specialis Principles of International Climate Law*, UTRECHT LAW REVIEW, 8(3) UTRECHT LAW REVIEW 7–37 (2012).

166 UNFCCC (1992), Art. 3(1).

167 Paris Agreement (2015), Art. 2(2).

168 Ibid, Art. 4.

human rights law.[169] On this matter, the U.N. Office of the High Commissioner for Human Rights ("**OHCHR**") has highlighted that ensuring equity in climate action is a key human rights obligation in the face of climate change.[170] This requires "that efforts to mitigate and adapt to the impacts of climate change should benefit people in developing countries, indigenous peoples, people in vulnerable situations and future generations."[171]

g. Obligation to Provide Remedies for Human Rights Violations Arising from Climate Change

89. Climate change mitigation measures must comply with human rights principles.[172] Justice Guha Roy has pointed out, social life is "unthinkable" without the timeless premise "[t]hat a wrong done to an individual must be redressed by the offender himself or by someone else against whom the sanction of the community may be directed."[173] Shelton has observed that "remedies are not only about making the victim whole; they express opprobrium to the wrongdoer from the perspective of society as a whole" and thus "affirm, reinforce, and reify the fundamental values of society."[174]

90. Thus, any legal system prevails when remedies are provided by the adjudicator to the victims upon whom any injury has been inflicted. In international human rights law, the right to a remedy is a substantive right that is well-established

[169] In this sense, the U.N. Special Rapporteur on the promotion and protection of human rights in the context of climate change has recognized that "the intersection of gender with race, class, ethnicity, sexuality, indigenous identity, age, disability, income, migrant status and geographical location often compound vulnerability to climate change impacts, exacerbate inequity and create further injustice." *See* U.N. General Assembly, *Report of the Special Rapporteur on the promotion and protection of human rights in the context of climate change; Promotion and protection of human rights in the context of climate change mitigation, loss and damage and participation*, A/77/226 (26 July 2022), ¶ 29. *See also*, OHCHR, FREQUENTLY ASKED QUESTIONS ON HUMAN RIGHTS AND CLIMATE CHANGE: FACT SHEET NO. 38 (2021), pp. 38, 42.

[170] OHCHR, FREQUENTLY ASKED QUESTIONS ON HUMAN RIGHTS AND CLIMATE CHANGE: FACT SHEET NO. 38 (2021), p. 33.

[171] OHCHR, FREQUENTLY ASKED QUESTIONS ON HUMAN RIGHTS AND CLIMATE CHANGE: FACT SHEET NO. 38 (2021), p. 42.

[172] Anne Kling, *Climate Change and human rights – Can the courts fix it?*, HEINRICH BÖLL STIFTUNG.

[173] Justice S.N. Guha Roy, *Is the Law of Responsibility of States for Injuries to Aliens a Part of Universal International Law?*, 55(4) AMERICAN JOURNAL OF INTERNATIONAL LAW 863 (1961).

[174] Dinah Shelton, *The Right to Reparations for Acts of Torture: What Right, What Remedies?*, 17(2) TORTURE 96 (2007), p. 96.

through both custom[175] and treaties.[176] In this respect, the European Court of Human Rights ("**ECtHR**") has emphasized that the purpose of human rights law is "[to guarantee] not rights that are theoretical or illusory but rights that are practical and effective."[177] Similarly, the African Commission on Human and Peoples' Rights has stressed that "[t]he rights and freedoms of individuals enshrined in the [African] Charter can only be fully realized if governments provide structures which enable them to seek redress if they are violated."[178] The Inter-American Court of Human Rights has similarly held that "a full and

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[175] *See Basic Principles and Guidelines on the Right to a Remedy and Reparation for Victims of Gross Violations of International Human Rights Law and Serious Violations of International Humanitarian Law*, U.N. General Assembly Res. 60/147 (16 December 2005), Annex, Principles 1(b), 2, 3 and (pertaining to gross violations of international human rights law and international crimes) 11. *See also Moiwana Village v. Suriname*, 124 IACtHR (Ser. C) (2005), ¶ 169. *See further* Dinah Shelton, REMEDIES IN INTERNATIONAL HUMAN RIGHTS LAW (2d ed. 2010), p. 103.

[176] International Covenant on Civil and Political Rights (adopted 16 December 1966; entered into force 23 March 1976), 999 UNTS 171, Art. 14; American Convention on Human Rights (22 November 1969), 1144 UNTS 123, Arts. 1, 8 and 25; Convention for the Protection of Human Rights and Fundamental Freedoms (European Convention on Human Rights, as amended) (2021), Art. 13. Since 2008, the Human Rights Council and its Special Procedures Mechanisms have been actively involved in addressing the human rights impacts of climate change. The Council has held two-panel discussions on human rights and climate change, which was also the theme of the 2010 Social Forum . The following resolutions on human rights and climate change have been issued to date:

• Resolution 7/23 (March 2008): The Council expressed concern that climate change "poses an immediate and far-reaching threat to people and communities around the world" and requested OHCHR to prepare a study on the relationship between climate change and human rights (A/HRC/10/61).

• Resolution 10/4 (March 2009): The Council noted that "climate change-related impacts have a range of implications, both direct and indirect, for the effective enjoyment of human rights …" and that such effects "will be felt most acutely by those segments of the population who are already in a vulnerable situation …"

• Resolution 18/22 (September 2011): The Council affirmed that human rights obligations, standards, and principles have the potential to inform and strengthen international and national policy-making in the area of climate change, promoting policy coherence, legitimacy, and sustainable outcomes. They called for a seminar to address the adverse impacts of climate change on the full enjoyment of human rights and a summary report of the seminar (A/HRC/20/7).

• Resolution 26/27 (July 2014): The Council emphasized the need for all States to enhance international dialogue and cooperation to address the adverse impacts of climate change on the enjoyment of human rights including the right to development. It called for dialogue, capacity building, mobilization of financial resources, technology transfer, and other forms of cooperation to facilitate climate change adaptation and mitigation, in order to meet the special needs and circumstances of developing countries.

• Resolution 29/15 (July 2015): The Council emphasized the importance of continuing to address the adverse consequences of climate change for all and called for a panel discussion and analytical study on the impacts of climate change on the enjoyment of the right to health.

[177] *See, for example*, *Airey v. Republic of Ireland*, 32 Eur Ct HR Ser. A, 2 EHRR 305 (1979). *See also* Stephen Humphreys, *Introduction: Human Rights and Climate Change*, in HUMAN RIGHTS AND CLIMATE CHANGE (2010), p. 11 (suggesting that the absence of a remedy for climate change victims would significantly undermine the hegemonic status (or aspiration) of human rights law).

[178] *Jawara v. The Gambia (Communication Nos. 147/95, 149/96)*, ACHPR 17 (2000), ¶ 74.

adequate reparation cannot be reduced to the payment of compensation to the victims or their families, since, depending on the case, rehabilitation measures, satisfaction and guarantees of non-repetition are also necessary."[179] In the context of climate change, specifically, the requirement for a remedy is a "key organising concept."[180]

91. With the link between human rights violations and the adverse impacts of climate change has been unequivocally established,[181] it becomes necessary to highlight the remedies that are available in such circumstances. Given the state of the climate crisis and the threat it imposes to the enjoyment of established human rights,[182] there is recognition in climate change law of "the right to remedy" when there is a violation of human rights due to the adverse effects of climate change.[183] Thus, "redress for injury is central to a human rights approach to climate change, and indeed is a basic axiom of justice."[184]

92. Victims of human rights violations—including those associated with climate change—are entitled to access remedial institutions and procedures affording

[179] *See, e.g.*, *Herrera Espinoza et al. v. Ecuador*, Judgment, 316 IACtHR (Ser. C) (2016), ¶ 314. *See also* U.N. Human Rights Committee, *General Comment No. 31*, CCPR/C/21/Rev.1/Add. 13 (26 May 2004), ¶ 2; Margaretha Wewerinke-Singh, *Remedies for Human Rights Violations Caused by Climate Change*, 9(3) CLIMATE LAW 224–243 (2019); Ilias Bantekas and Lutz Oette, INTERNATIONAL HUMAN RIGHTS LAW AND PRACTICE (2nd ed., 2013), p. 92.

[180] *See* James R Crawford, *Responsibility to the International Community as a Whole*, 8(2) IND. J. GLOBAL LEGAL STUD. 303, 313 (2001); Benedict Kingsbury, *Sovereignty and Inequality*, 9 EUR.J.INT'LL. 599, 599 (1998); Christopher G. Weeramantry, UNIVERSALISING INTERNATIONAL LAW (2004), p. 38 ("Whether we like it or not, the sovereign state system provides the basis of current international law"); UNFCCC (1992), Preamble ("Reaffirming the principle of sovereignty of States in international cooperation to address climate change"); U.N. Human Rights Council, *Report of the Office of the United Nations High Commissioner for Human Rights on the relationship between climate change and human rights*, A/HRC/10/61 (15 January 2009).

[181] The UNGA recognizes the right to a clean, healthy and sustainable environment as a human right. *See* UNHRC, *The human right to a safe, clean, healthy and sustainable environment*, A/HRC/48/L.23/Rev.1 (2021). In the Torres Strait Case, the UNHRC has found that Australia's failure to adequately protect indigenous Torres Islanders against adverse impacts of climate change violated their rights to enjoy their culture and be free from arbitrary interferences with their private life, family and home. *See* U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 September 2022); Paris Agreement (2015), Preamble. *See also* Glasgow Climate Pact (2021), Decision 1/CP.26 and Decision 1/CMA.3, preambular ¶ 6.

[182] *See* U.N. Human Rights Council, *Report of the Office of the United Nations High Commissioner for Human Rights on the relationship between climate change and human rights*, A/HRC/10/61 (15 January 2009). The report comments on five thematic areas: (a) the relationship between the environment and human rights; (b) implications of the effects of climate change for the enjoyment of specific rights; (c) vulnerabilities of specific groups; (d) human rights implications of climate change-induced displacement and conflict; and (e) human rights implications of measures to address climate change.

[183] See Margaretha Wewerinke-Singh, *Remedies for Human Rights Violations Caused by Climate Change*, 9(3) CLIMATE LAW 224–243, 226 (2019).

[184] Ibid, p. 2; *see also* Margaretha Wewerinke-Singh, STATE RESPONSIBILITY, CLIMATE CHANGE AND HUMAN RIGHTS UNDER INTERNATIONAL LAW (2019).

them a fair hearing and, ultimately, substantive redress.[185] The importance of access to independent judicial or quasi-judicial bodies that can adjudicate human rights violations is such that the element of enforceability is sometimes included in the notion of legal rights.[186] Without this element, the obligations of states are all too easily mischaracterized as voluntary commitments that may be upheld or disregarded at will.[187]

93. Providing access to justice on environmental matters is a procedural obligation.[188] In this sense, the Inter-American Court of Human Rights ("**IACtHR**") has established that "access to justice permits the individual to ensure that environmental standards are enforced and provides a means of redressing any human rights violations that may result from failure to comply with environmental standards, and includes remedies and reparation."[189] Consequently, States are bound to "guarantee that the public have access to remedies conducted in accordance with due process of law to contest any provision, decision, act or omission of the public authorities that violates or could violate obligations under environmental law; to ensure the full realization of the other procedural rights . . . and to redress any violation of their rights as a result of failure to comply with obligations under environmental law."[190]

94. Referring specifically to effective remedies that must be provided for human rights violations arising from climate change, the OHCHR has also recognized that access to justice must be guaranteed to those who suffer violations to their climate-related human rights, so that they have access to "meaningful remedies," including judicial and other mechanisms.[191] Similarly, the IACtHR has considered

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[185] Ibid.

[186] Morris Ginsberg, ON JUSTICE IN SOCIETY (1965), p. 74.

[187] *See* Dinah Shelton, *The Right to Reparations for Acts of Torture: What Right, What Remedies?*, 17(2) TORTURE 96 (2007), p. 96.

[188] UNECE, Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters ("**Aarhus Convention**") (25 June 1998), Art. 9; Regional Agreement on Access to Information, Public Participation and Access to Justice in Environmental Matters in Latin America and the Caribbean ("**Escazú Agreement**") (4 March 2018), Art. 8.

[189] *State Obligations in Relation to the Environment in the Context of the Protection and Guarantee of the Rights to Life and Personal Integrity: Interpretation and Scope of Articles 4(1) and 5(1) in Relation to Articles 1(1) and 2 of the American Convention on Human Rights*, Advisory Opinion OC-23/17 (Requested by the Republic of Colombia), IACthR (15 November 2017), ¶ 234; Maria Antonia Tigre & Natalia Urzola, *The 2017 Inter-American Court's Advisory Opinion: changing the paradigm for international environmental law in the Anthropocene*, 12(1) J. HUM. RTS. & ENVT. 24 (2021).

[190] *State Obligations in Relation to the Environment in the Context of the Protection and Guarantee of the Rights to Life and Personal Integrity: Interpretation and Scope of Articles 4(1) and 5(1) in Relation to Articles 1(1) and 2 of the American Convention on Human Rights*, Advisory Opinion OC-23/17 (Requested by the Republic of Colombia), IACthR (15 November 2017), ¶ 237.

[191] OHCHR, FREQUENTLY ASKED QUESTIONS ON HUMAN RIGHTS AND CLIMATE CHANGE: FACT SHEET NO. 38 (2021), p. 32.

that "States should take appropriate measures to ensure that individuals and communities affected by human rights abuses and violations under their jurisdiction have access to effective redress mechanisms, including the accountability of companies and the determination of their criminal, civil or administrative responsibility. In case of violation of rights as a result of environmental damage, States have the obligation to make full reparation to the victims, which implies the restoration of the environment as a mechanism of integral restitution and guarantee of non-repetition."[192]

95. It must be clarified that domestic authorities are primarily responsible to ensure that human rights are enforced within their jurisdiction, and therefore States must ensure effective domestic remedies for addressing human rights violations arising from climate change. Where these remedies are not available, or are not effective in practice, universal and regional human rights systems might be triggered for victims of human rights violations caused by climate change.[193]

h. Good Faith

96. The notion of good faith reflects legal and extra-legal elements, such as honesty, fairness, and reasonableness. Although the meaning of the principle of good faith in international law is ambiguous and controversial in theory and practice, good faith in international law has manifold roles in the creation, interpretation, and performance of treaties as well as in the creation and performance of international obligations derived from other sources of international law. In this sense, good faith is a fundamental principle of international law.

97. Recent cases brought before the ICJ have elaborated the principle of good faith in fulfilment of a duty of cooperation, and have revealed the substance of the principle under concrete circumstances related to sustainable development and, more specifically, to sustainable management of shared resources in international law. In the *Gabčikovo-Nagymaros Project* case, within the realm of cooperation in the use of the shared water resources contemplated by the 1977 Treaty between the parties, the Court called upon the parties to re-negotiate and re-establish the joint regime in good faith under the rule of *pacta sunt servanda*, taking into consideration newly developed environmental norms even after the construction began. The Court indicated that "[w]hat is required in the present case by the rule *pacta sunt servanda* as reflected in Article 26 of the Vienna Convention of 1969 on the Law of Treaties, is that the Parties find an agreed solution within the co-operative context of the Treaty."[194] The Court construed good faith under Article 26, such that "[t]he

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[192] Inter-American Commission on Human Rights, *Climate Emergency: Scope of Inter-American Human Rights Obligations*, Resolution No. 3/2 (2021), Point II.14.
[193] *See* U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022).
[194] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Judgment, ICJ Reports 1997 (25 September 1997), ¶ 142.

principle of good faith obliges the Parties to apply the 1977 Treaty in a reasonable way and in such a manner that its purpose can be realized."[195] For the Court, the cooperative context of the 1977 Treaty was meant to re-establish the joint regime for the common utilization of the shared water resources.

i. Public Participation

98. Public participation refers to the ability of citizens representing different perspectives to inform governmental decision making.[196] Public participation rights in private decision making, such as within corporations, are far rarer. The perspectives that a participating public can bring to bear on governmental decision making include both those of the affected public and those of experts and researchers in a variety of fields who operate independently of the government.[197] Thus, public participation serves a variety of purposes from increasing the legitimacy of governmental decisions to ensuring that substantively, the government has not missed or ignored an important aspect, impact, or unintended consequence of the decision under consideration.[198] This has been recognized as a right in many international human rights instruments such as the Universal Declaration on Human Rights[199] and the International Covenant on Civil and Political Rights.[200]

99. In the cross-pollination between human rights law and international environmental law, public participation has been an important element in environmental decision-making for several decades. It has been enshrined in international environmental law via such instruments as the 1992 Rio Declaration[201] and the 1998 UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters

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[195] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Judgment, ICJ Reports 1997 (25 September 1997), ¶ 142.
[196] Sanne Akerboom & Robin Kundis Craig, *How law structures public participation in environmental decision making: A comparative law approach*, 32(3) ENVIRONMENTAL POLICY AND GOVERNANCE, 232–246 (2022); Caron Chess & Kristen Purcell, *Public participation and the environment: Do we know what works?*, 33(16) ENVIRONMENTAL SCIENCE & TECHNOLOGY, 2685–2692 (1999); Anna Wesselink, Jouni Paavola, Oliver Fritsch, & Ortwin Renn, *Rationales for public participation in environmental policy and governance: Practitioners' perspectives*, 43(11) ENVIRONMENT & PLANNING A: ECONOMY AND SPACE, 2688–2704 (2011).
[197] Sanne Akerboom & Robin Kundis Craig, *How law structures public participation in environmental decision making: A comparative law approach*, 32(3) ENVIRONMENTAL POLICY AND GOVERNANCE, 232–246 (2022).
[198] Salim Momtaz & William Gladstone, *Ban on commercial fishing in the estuarine waters of New South Wales, Australia: Community consultation and social impacts*, 28(2-3) ENVIRONMENTAL IMPACT ASSESSMENT REVIEW, 319–342 (2008); *see also* Ciaran O'Faircheallaigh, *Public participation and environmental impact assessment: Purposes, implications, and lessons for public policy making*. 30(1) ENVIRONMENTAL IMPACT ASSESSMENT REVIEW, 19–27 (2010).
[199] Universal Declaration on Human Rights (1948), Art. 21.
[200] International Covenant on Civil and Political Rights (adopted 16 December 1966; entered into force 23 March 1976), 999 UNTS 171, Art. 25.
[201] Rio Declaration (1992), Principle 10.

("**Aarhus Convention**").[202] It has also been recognized in the Stockholm Convention on Persistent Organic Pollutants,[203] the Convention on Biological Diversity,[204] the United Nations Convention to Combat Desertification[205], and the United Nations Framework Convention on Climate Change.[206] At a regional level, the Escazú Agreement enshrines the right of every person of present and future generations to live in a healthy environment and to sustainable development.[207] It is the Economic Commission for Latin America and the Caribbean's ("**ECLAC**") first environmental treaty as well as the world's first agreement with provisions on human rights defenders in environmental matters, an issue of particular importance in the region due to risks for advocates and activists.[208]

100. Public participation has three components: the right to participate in environmental decision-making processes, the right to information concerning the environment and activities affecting it, and the right of access to justice.[209] The most significant development of promoting public participation in international environmental law was the adoption of the Aarhus Convention.[210] It was a major step forward in the field of procedural environmental rights. For the first time the interlinked rights of access to information, public participation, and access to justice were addressed in a comprehensive way in a single international treaty and is widely accepted[211] as the leading example of the implementation of principle 10 of the Rio Declaration on Environment and Development.[212]

101. The adoption of this established that sustainable development can be achieved only through the involvement of all stakeholders, linking government accountability and environmental protection. It sets out the key elements of public participation and its provisions have become widely recognized as a benchmark for environmental democracy. The key elements include access to environmental

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202 Aarhus Convention (25 June 1998), Arts. 6–8.
203 Stockholm Convention on Persistent Organic Pollutants (2001), Art. 10.
204 CBD (1992), Art. 14(1).
205 United Nations Convention to Combat Desertification (1994), Arts. 3, 5.
206 UNFCCC (1992), Art. 6(a).
207 Escazú Agreement (4 March 2018), Art. 3.
208 "*Escazú Agreement Takes Effect, Enshrining Right to Sustainable Development*," IISD SDG KNOWLEDGE HUB (26 April 2021).
209 Tori Chai, "*The Importance of Public Participation*," YORK UNIVERSITY ENVIRONMENTAL JUSTICE AND SUSTAINABILITY CLINIC (1 April 2016).
210 See supra at note 202.
211 Forty-six states and the EU are Parties to this Convention, along with transitioning economies including those from Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan) and Caucasian countries (namely Armenia, Azerbaijan and Georgia). All other former Soviet countries such as Ukraine, Belarus, and the Republic of Moldova are also Parties to the Convention. In addition, most Balkan non-EU countries, such as Albania, Bosnia and Herzegovina, Montenegro, Serbia, and the former Yugoslav Republic of Macedonia, are also Parties.
212 Patricia Birnie and Alan Boyle, INTERNATIONAL LAW AND THE ENVIRONMENT (2001), p. 262.

information, early and ongoing involvement of the public in decision-making, broad scope of participation, transparent and user-friendly processes, an obligation on authorities to take account of public input, a supportive infrastructure, and an effective means of enforcement/appeal.

2. *Treaty Law*

102. The UNFCCC[213] and the Paris Agreement[214] notably foreground three shared principles of international environmental law: common, but differentiated responsibilities, cost lowering, and the primacy of states as actors.[215] Comparing the UNFCCC to the Paris Agreement reveals the continuities and evolutions of each of these principles.[216]

103. The UNFCCC and the Paris Agreement both recognize that state parties share a common goal in reducing GHG emissions, and that each state party has *sui generis* responsibilities towards achieving that goal. This phrase was first articulated in the UNFCCC, which divided the global community into three tranches of responsibility: Annex I, Annex II, and developing countries.[217] High-income nations are commanded to commit themselves to bear greater responsibility for historical GHG emissions, as well as to facilitate financial flows to developing nations. The UNFCCC lists several geoeconomic conditions that may differentiate a state party's commitments.[218] The Paris Agreement highlights the heightened challenges and greater leeway granted to "[t]he least developed countries and *small island developing States*" (alteration in original) (emphasis added).[219] The treaties recognize both individual state actors and their collective capacity to reduce GHG emissions.

104. Both treaties seek to lower costs through efficacious financial flows from high-income nations to lower income nations, increased transparency, and technology sharing. The UNFCCC requires high-income nations to commit "additional financial resources" to low-to-middle-income nations.[220] Similarly, the Paris Agreement beseeches high-income nations to support financially low-to-middle-

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[213] *See generally* UNFCCC (1992).
[214] *See* Paris Agreement (2015).
[215] See David Hunter, *International Environmental Law*, American Bar Association, 19(1) INSIGHTS ON LAW AND SOC'Y (5 January 2021) (listing ten principles of international environmental law).
[216] The principles discussed in this memo are non-exhaustive. *See* id.
[217] *See* UNFCCC (1992), Art. 4, pp. 23-24 (defining Annex I countries to include high-income nations, plus post-Soviet states, Annex II consisting of the same countries as Annex I minus the post-Soviet states, and developing countries to encompass all other party states).
[218] *See* id., Art. 4, pp. 8–9 (including notably "small island countries").
[219] Id.
[220] *See* UNFCCC (1992), Art. 4(3).

income nations.[221] The UNFCCC and the Paris Agreement both see increased transparency as a means of lowering information costs and promoting effective governance.[222] Parties to the UNFCCC are committed to sharing technology and scientific information that will reduce the magnitude of climate change's effects.[223] The Paris Agreement advances the UNFCCC's commitments by beseeching high-income nations to make technological transfers to low-to-middle-income countries.[224] Both treaties evince an underlying belief in the importance of cost lowering across financial, information, and technological flows.

105. Both treaties prioritize state actor agency. In Article 4 of the UNFCCC, individual state actors are the agents through which any cooperative framework may emerge.[225] Each State's pledges to reduce its GHG emissions are expressed in its "nationally determined contributions" ("**NDCs**"). These treaties both treat the nation-state as the fundamental unit of agency for GHG reduction and climate change cooperation.

B. Relevant Principles of International Human Rights Law

106. The request for an advisory opinion poses questions about States' obligations in respect of the climate system and the environment. By their nature, these questions implicate the connection between international environmental law and international human rights law,[226] a well-established body of international law comprised of many obligations derived from treaty and customary international law. The Court has previously recognized this connection, as follows:

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[221] *See* Paris Agreement (2015), Art. 4(5) ("Support shall be provided to developing country Parties for . . . implementation . . . recognizing that enhanced support for developing country Parties will allow for higher ambition in their actions.").

[222] Paris Agreement (2015), Art. 13(1) ("[T]o promote effective implementation, an enhanced transparency framework for action and support, with built-in flexibility which takes into account Parties' different capacities and builds upon collective experience is hereby established"); UNFCCC (1992), Art. 11(2) ("The financial mechanism shall have an equitable and balanced representation of all Parties *within a transparent system* of governance" (emphasis added)).

[223] UNFCCC (1992), Art. 4, p. 6.

[224] Paris Agreement (2015), Art. 13(9) ("Developed country Parties *shall*, and other Parties that provide support should, provide information on financial, technology transfer and capacity-building support provided to developing country Parties . . . ." (emphasis added)).

[225] *See* UNFCCC (1992), Art. 4, pp. 4–5.

[226] *See, e.g.*, U.N. Environment Programme, *Declaration of the United Nations Conference on the Human Environment*, in *Report of the United Nations Conference on the Human Environment*, A/CONF.48/14/Rev. 1 (1972), Principle 1 ("Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generations."); U.N. Environment Programme, *Report of the United Nations Conference on the Human Environment*, A/CONF.48/14/Rev. 1 (1972), p. 3 ("Both aspects of man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights – even the right to life itself").

> The Court also recognizes that the environment is not an abstraction but represents the living space, the quality of life and the very health of human beings, including generations unborn. The existence of the general obligation of States to ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control is now part of the corpus of international law relating to the environment.[227]

107. Because harm to the environment may threaten human health and quality of life, States' obligations with respect to the environment are inherently tied to their human rights obligations. The following sections identify and briefly discuss certain human rights principles that are relevant to and inform States' obligations with respect to the environment.

1. *Right to life*

108. The right to life is a well-established principle of treaty law and customary international law.[228] The International Covenant on Civil and Political Rights ("**ICCPR**"), which is the foundational multilateral human rights treaty, codifies this right:

> Every human being has the inherent right to life. This right shall be protected by law. No one shall be arbitrarily deprived of his life.[229]

109. The U.N. Human Rights Committee is a body of independent experts charged with monitoring the implementation of the ICCPR, and the Committee issues authoritative interpretations of the rights codified therein. In this respect, the

[227] *Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion, ICJ Reports 1996 (8 July 1996), ¶ 29. *See also Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, Vice-President Weeramantry Separate Opinion, ICJ Reports 1997 (25 September 1997), p. 91 (describing the protection of the environment as a "sine qua non for numerous human rights such as the right to health and the right to life itself").

[228] Universal Declaration of Human Rights (1948), Art. 3; ICCPR (1966), Art. 6; Convention for the Protection of Human Rights and Fundamental Freedoms (European Convention on Human Rights, as amended) (2021), Art. 2; African Charter on Human and People's Rights (1981), Art. 4; Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa (2003), Art. 4; African Charter on the Rights and Welfare of the Child (signed July 1990; entered into force 29 November 1999), Art. 5; Arab Charter on Human Rights (2004), Arts. 5, 6; American Declaration of the Rights and Duties of Man (1948), Art. 1; American Convention on Human Rights (22 November 1969), 1144 UNTS 123, Art. 4; Inter-American Convention on the Prevention, Punishment and Eradication of Violence against Women "Convention of Belém do Pará" (1994), Art. 4; U.N. Human Rights Committee, *General Comment No. 36 on Article 6: right to life*, CCPR/C/GC/36 (30 October 2018); African Commission on Human and People's Rights, *General Comment No. 3 On The African Charter On Human And Peoples' Rights: The Right To Life* (2015).

[229] ICCPR (1966), Art. 6(1). *See also* Universal Declaration of Human Rights (1948), Art. 3 ("Everyone has the right to life, liberty and security of person.").

Committee has affirmed that the right to life includes a corresponding obligation on the part of States to protect such right:

> [T]he right to life cannot be properly understood if it is interpreted in a restrictive manner, and . . . the protection of that right requires States parties to adopt positive measures to protect the right to life.[230]

110. Furthermore, the Human Rights Committee has expressly recognized that the obligation to protect the right to life encompasses obligations with respect to the environment:

> The duty to protect life also implies that States parties should take appropriate measures to address the general conditions in society that may give rise to direct threats to life or prevent individuals from enjoying their right to life with dignity. These general conditions may include . . . degradation of the environment.[231]

111. More specifically:

> Environmental degradation, climate change and unsustainable development constitute some of the most pressing and serious threats to the ability of present and future generations to enjoy the right to life. **The obligations of States parties under international environmental law should thus inform the content of article 6 of the Covenant, and the obligation of States parties to respect and ensure the right to life should also inform their relevant obligations under international environmental law**. Implementation of the obligation to respect and ensure the right to life, and in particular life with dignity, depends, inter alia, on measures taken by States parties to preserve the environment and protect it against harm, pollution and climate change caused by public and private actors. **States parties should therefore ensure**

[230] U.N. Human Rights Committee, *Views adopted by the Committee under article 5 (4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 July 2022). *See also, e.g.*, *Understanding Human Rights and Climate Change*, Submission of the Office of the High Commissioner for Human Rights to the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (2021), p. 13 ("All States have committed to respect, protect, promote, and fulfil the right to life. This entails, at the very least, that States should take effective measures against foreseeable and preventable loss of life."); *Osman v. the United Kingdom*, Judgment, Reports 1998-VIII (28 October 1998), p. 3159, § 115; *L.C.B. v. the United Kingdom*, Judgment, Reports of Judgments and Decisions 1998-III (9 June 1998), p. 1403, § 36; *Paul and Audrey Edwards v. the United Kingdom*, no. 46477/99, Judgment, ECHR 2002-II (13 March 2002), § 54; *İlhan v.Turkey [GC]*, no. 22277/93, Judgment, ECHR 2000-VII (27 June 2000), § 91; *Kılıç v. Turkey*, no. 22492/93, Judgment, ECHR 2000-III (28 March 2000), § 62; and *Mahmut Kaya v. Turkey*, no. 22535/93, Judgment, ECHR 2000-III (28 March 2000), § 85.

[231] U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 July 2022), ¶ 8.3.

> **sustainable use of natural resources, develop and implement substantive environmental standards**, conduct environmental impact assessments and consult with relevant States about activities likely to have a significant impact on the environment, provide notification to other States concerned about natural disasters and emergencies and cooperate with them, provide appropriate access to information on environmental hazards and pay due regard to the precautionary approach.[232] (Emphasis added)

112. Importantly, the Committee has also recognized that "the obligation of States parties to respect and ensure the right to life **extends to reasonably foreseeable threats and life-threatening situations that can result in loss of life**"[233] (emphasis added). "[S]uch threats may include adverse climate change impacts," as "environmental degradation, climate change and unsustainable development constitute some of the most pressing and serious threats to the ability of present and future generations to enjoy the right to life."[234]

113. Furthermore, a State's obligations are not purely territorial, but extend beyond the State's national borders:

> States parties must take appropriate measures to protect individuals against deprivation of life by other States, international organizations and foreign corporations operating within their territory or in other areas subject to their jurisdiction. They must also take appropriate legislative and other measures to ensure that all activities taking place in whole or in part within their territory and in other places subject to their jurisdiction, but having a direct and reasonably foreseeable impact on the right to life of individuals outside their territory, including activities taken by corporate entities based in their territory or subject to their jurisdiction.[235]

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[232] U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 July 2022), ¶ 8.3.
[233] U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 July 2022), ¶ 8.3.
[234] U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 July 2022), ¶ 8.3.
[235] U.N. Human Rights Committee, *General Comment No. 36 on Article 6: right to life*, CCPR/C/GC/36 (30 October 2018), ¶ 22. *See also* U.N. Human Rights Committee, *General Comment No. 31*, CCPR/C/21/Rev.1/Add. 13 (26 May 2004), ¶ 10; U.N. Human Rights Committee, *Concluding observations: United Kingdom of Great Britain and Northern Ireland* (2008), ¶ 14; U.N. Human Rights Committee, *Decision adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication no. 2285/2013* (*Yassin et al. v. Canada*) (26 July 2017), ¶ 6.5; U.N. Human Rights Committee, *Concluding observations on the 6th periodic report of Canada* (2015), ¶ 6; U.N. Human Rights Committee, *Concluding observations on the 6th periodic report of Germany* (2012), ¶ 16; U.N. Human Rights Committee, *Concluding observations on the 4th periodic report of the Republic of South Korea* (2015), ¶ 10.

114. In short, the authoritative interpreter of the ICCPR has confirmed that one of the principal human rights obligations—namely, the obligation to protect the right to life—encompasses duties to prevent harm to the environment, including through climate change.[236] Such obligation has likewise been recognized by courts and tribunals in the context of domestic[237] and international[238] litigation.

2. *Right to self-determination*

[236] Interpretations of other human rights treaties are in accord. *See, e.g.*, *General Comment No. 3 On The African Charter On Human And Peoples' Rights: The Right To Life* (2015), ¶ 41 ("The right to life should be interpreted broadly. The State has a positive duty to protect individuals and groups from real and immediate risks to their lives caused either by actions or inactions of third parties. In cases where the risk has not arisen from malicious or other intent then the State's actions may not always be related to criminal justice. Such actions include, inter alia, preventive steps to preserve and protect the natural environment and humanitarian responses to natural disasters, famines, outbreaks of infectious diseases, or other emergencies.").

[237] *See, e.g.*, *Urgenda Foundation v. the Netherlands*, Judgment, Dutch Supreme Court (Hoge Raad), No. 19/00135, ECLI:NL:HR:2019:2006 (20 December 2019); *Milieudefensie et al. v. Royal Dutch Shell plc*, Judgment, Hague District Court, C/09/571932 (26 May 2021) (appeal pending); *VZW Klimaatzaak v. Kingdom of Belgium and Others*, Civ. [Tribunal of First Instance] Bruxelles (4th ch.), Case 2015/4585/A (17 June 2021) (appeal pending) (holding that by failing to take sufficient climate action to protect the life and privacy of the plaintiffs, the defendants were in breach of their obligations under Articles 2 and 8 of the European Convention on Human Rights); *Ashgar Leghari v. Federation of Pakistan*, Order Sheet, Lahore High Court, W.P. No. 25501/2015 (4 September 2015) (holding the national government had violated the fundamental rights of its citizens, including the right to life, by failing to implement adaptation measures recommended in the 2012 National Climate Policy and Framework); *Subhash Kumar v. State of Bihar*, Judgment, Supreme Court of India, AIR 1991 SC 420 (1 September 1991) (holding that the right to a safe environment was integral to the right to life under Article 21 of the Indian Constitution); *I.L. v. Italian Ministry of the Interior and Attorney General at the Court of Appeal of Ancona*, Judgment, Supreme Court of Cassation – Second Civil Section, n. 5022/2021 (24 February 2021).

[238] *See, e.g.*, *Yanomami v. Brazil, Case 7615*, Inter-Am. Ct. H.R., Resolution No. 12/85, OAS/Ser. L/V/II.66 (5 March 1985) (finding that Brazil had violated the rights to life, liberty and personal security of the Yamomani Indians by failing to take measures to prevent environmental degradation); *Budayeva and Others v. Russia*, 2008-II Eur. Ct. H.R. 267 (2008), ¶¶ 128–130, 133 and 159 (holding states must also take reasonable measures to protect citizens against the reasonably foreseeable effects of natural disasters); U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 2751/2016 (Portillo Cáceres and Others v. Paraguay)*, CCPR/C/126/D/2751/2016 (25 July 2019); *Öneryildiz v. Turkey*, Judgment, 2002-XII Eur. Ct. H.R. 79 (2004); *Kawas-Fernández v. Honduras, Judgment*, 196 Inter-Am. Comm'n H.R. (Ser. C) (3 April 2009), ¶ 148; *Özel and Others v. Turkey*, 2016-II Eur. Ct. H.R. 364 (2015), ¶¶ 170–171 and 200; *Social and Economic Rights Centre (SERAC) and Centre for Economic and Social Rights (CESR) v. Nigeria*, Communication No. 155/96, African Commission on Human and Peoples' Rights [Afr. Comm'n H.P.R.]) (27 October 2001), ¶ 67; U.N. Human Rights Committee, *View adopted by the Committee under article 5 (4) of the Optional Protocol, concerning communication No. 2728/2016 (Teitiota v. New Zealand)*, CCPR/C/127/D/2728/2016 (24 October 2019), ¶ 9.9; U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (22 July 2022).

115. The right to self-determination is a fundamental human right, which has been recognized by the ICJ,[239] and which is codified in the U.N. Charter, Article 1 of which provides:

> The Purposes of the United Nations are: . . .
>
> 2. To develop friendly relations among nations based on respect for the principle of equal rights and self-determination of peoples, and to take other appropriate measures to strengthen universal peace.[240]

116. The right to self-determination is likewise codified in the ICCPR:

> All peoples have the right of self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development.[241]

117. The right to self-determination encompasses the requirement to ensure the full enjoyment of subsidiary rights, including social, cultural, and economic rights.[242] Such subsidiary rights include the right to life, adequate food, water, health, adequate housing, productive use and enjoyment of property, cultural practices and traditions.

118. Environmental degradation and climate change affect and potentially infringe upon these subsidiary rights. In particular, GHG emissions threaten natural environments, endanger human life, imperil food and water systems, and undermine the ability of peoples to enjoy suitable standards of living.[243] Furthermore, a people cannot exercise sovereignty over natural resources when the environment that bears those resources is not healthy and is therefore less capable, or entirely incapable, of producing those resources.[244] The risk is

[239] *See East Timor (Portugal v. Australia)*, Judgment, ICJ Reports 1995 (30 June 1995), ¶ 29; *Legal Consequences for States of the Continued Presence of South Africa in Namibia (South West Africa) notwithstanding Security Council Resolution 276 (1970)*, Advisory Opinion, ICJ Reports 1971 (21 June 1971).
[240] U.N. Charter, Art. 1.
[241] International Covenant on Civil and Political Rights (adopted 16 December 1966; entered into force 23 March 1976), 999 UNTS 171, ¶ 1. *See also* International Covenant on Economic, Social and Cultural Rights (11 December 1966), 993 UNTS 3, Art. 1, ¶ 1–2 ("All peoples have the right of self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development. 2. All peoples may, for their own ends, freely dispose of their natural wealth and resources without prejudice to any obligations arising out of international economic co-operation, based upon the principle of mutual benefit, and international law. In no case may a people be deprived of its own means of subsistence.").
[242] *See* Tekau Frere, *Climate Change and Challenges to Self-Determination: Case Studies from French Polynesia and the Republic of Kiribati*, 129 YALE LAW J. (2020).
[243] U.N. Human Rights Council, *Resolution 16/11: Human Rights and the Environment*, A/HRC/RES/16/11 (12 April 2011), p. 2.
[244] *See also Res. 1803 (XVII), Permanent Sovereignty over Natural Resources*, U.N. General Assembly Res. 1803 (14 December 1962) (establishing rights and restrictions for national sovereignty over natural resources).

increased for small island developing States, the territory of which is physically threatened by rising sea levels.[245] Indeed, islander and indigenous communities are at risk of forcible relocation, which could cause loss of personal and cultural identity, loss of physical connection with ancestral land, and loss of effective nationality.[246] Accordingly, the right to self-determination—and States' obligations thereunder—is inherently linked to climate change and environmental degradation.[247]

3. *Right to healthy environment*

119. The right to a healthy environment has been recognized in various treaties, including the African Charter on Human and People's Rights,[248] the Arab Charter on Human Rights,[249] the UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters,[250] Protocol of San Salvador to the American Convention on Human Rights,[251] the Escazú Agreement,[252] and the Charter of Fundamental Rights of the European Union.[253]

120. Furthermore, various international courts and U.N. organs and agencies have recognized the right to a healthy environment, including (i) the U.N. General Assembly, which has recognized "the right to a clean, healthy and sustainable environment as a human right;"[254] (ii) the UNHRC, which took note of "the right to a clean, healthy and sustainable environment as a human right that is important

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[245] *See* Tekau Frere, *Climate Change and Challenges to Self-Determination: Case Studies from French Polynesia and the Republic of Kiribati*, 129 YALE LAW J. (2020).
[246] U.N. Charter, Art. 15(2).
[247] U.N. Human Rights Council, *Report of the Human Rights Council on its tenth session*, A/HRC/10/29 (2009) (recognizing that self-determination is one of the human rights most affected by climate change).
[248] African Charter on Human and People's Rights (1981), Art. 24.
[249] Arab Charter on Human Rights (2004), Art. 38.
[250] Aarhus Convention (25 June 1998), preamble.
[251] Protocol of San Salvador to the American Convention on Human Rights (22 November 1969), 1144 UNTS 123, Art. 11. *See also State Obligations in Relation to the Environment in the Context of the Protection and Guarantee of the Rights to Life and Personal Integrity: Interpretation and Scope of Articles 4(1) and 5(1) in Relation to Articles 1(1) and 2 of the American Convention on Human Rights*, Advisory Opinion OC-23/17 (Requested by the Republic of Colombia), IACthR (15 November 2017), ¶ 79 (the right to a healthy environment under Article 11 of the San Salvador Protocol protects individuals and collectives, including future generations, and can be used to hold States responsible for cross-border violations that are within their "effective control").
[252] *See* Escazú Agreement (4 March 2018), Arts. 1 and 4 (the first environmental treaty of Latin America and the Caribbean; entered into force on 22 April 2021).
[253] Charter of Fundamental Rights of the European Union (2000), Art. 37 (providing that a high level of environmental protection must be integrated in EU policies).
[254] U.N. General Assembly, *The Human Right to a Clean, Healthy and Sustainable Environment*, A/RES/76/300 (28 July 2022).

for the enjoyment of human rights;"[255] (iii) the U.N. Special Rapporteur on Human Rights and the Environment;[256] (iv) the IActHR, which found that certain logging activities violated indigenous communities' right to a healthy environment;[257] and (v) the African Commission on Human and People's Rights.[258] Most recently, the UNHRC expressly recognized the right to a clean, healthy and sustainable environment as a human right in a resolution adopted in April 2023.[259]

121. The right to a healthy environment also enjoys constitutional protection in 110 States,[260] and domestic courts have enforced such rights.[261]

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[255] UNHRC, *Resolution adopted by the Human Rights Council on 8 October 2021: The human right to a clean, healthy, and sustainable environment*, HRC/RES/48/13 (8 October 2021).

[256] UNHRC, *Report of the Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy and Sustainable Environment*, A/HRC/37/59 (24 January 2018), ("States should ensure a safe, clean, healthy and sustainable environment in order to respect, protect and fulfill human rights.").

[257] *Indigenous Communities of the Lhaka Honhat Association v. Argentina*, Judgment, 400 IACtHR (Ser. C) (6 February 2020), ¶ 289.

[258] Social and Economic Rights Action Center & the Center for Economic and Social Rights v. Nigeria (Communication No. 155/96) (pollution caused by the oil industry violated the Ogoni people's right to a healthy environment under Art. 24 of the African Charter).

[259] *See* UNHRC, *Human Rights Council Adopts Eight Resolutions, Extends Mandates on Sale and Sexual Exploitation of Children, Iran, Democratic People's Republic of Korea, Belarus, and Syria* (4 April 2023).

[260] UNHRC, *Right to a healthy environment: good practices; Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment*, A/HRC/43/53 (30 December 2019). *See also, e.g.*, Conseil d'Etat, *6ème et 1ère sous-sections réunies, mentionné aux tables du recueil Lebon*, No. 243802 (5 July 2004), Arts. 1, 2, 5; Basic Law for the Federal Republic of Germany in the revised version published in the Federal Law Gazette Part III, classification number 100-1, as last amended by the Act of 28 June 2022 (28 June 2022), Article 20a (unofficial translation: ""Mindful also of its responsibility toward future generations, the state shall protect the natural foundations of life and animals by legislation and, in accordance with law and justice, by executive and judicial action, all within the framework of the constitutional order").

[261] *See, e.g.*, *Dover District Council v. CPRE Kent*, Judgment, [2017] UKSC 79 (6 December 2017) (appeal taken from Eng.) (referring to the Aarhus Convention to affirm the existence of the human right to a healthy environment); *Francisco Chahuan Chahuan v. Empresa Nacional de Petróleos, ENAP S.A*, Judgment, Case No. 5888-2019 (28 May 2019) (adjudicating Chile's failure to address industrial air pollution in the Quintero-Puchuncaví region constituted a violation); Cour Administrative d'Appel de Nantes, *2ème Chambre*, No. 07NT03775 (1 December 2009) (holding the State liable for activities that produced water contamination); Decision 7 C 30/17, German Federal Administrative Court (27 February 2018); *Ruling on Modification to Ethanol Fuel Rule*, Supreme Court of Mexico (Second Chamber), Amparo 610/2019 (22 January 2020) (relying on the Ramsar Convention on Wetlands of International Importance to determine if the destruction of a mangrove forest violated the constitutional right to a healthy environment); *Ashgar Leghari v. Federation of Pakistan*, Lahore High Court, W.P. No. 25501/201 (April 2015) (finding the government violated the National Climate Change Policy of 2012 and the Framework for Implementation of Climate Change Policy (2014-2030) by failing to meet goals set by the policies, and reasoning that the constitutional rights to life and human dignity (under articles 9 and 14 of the Constitution) included the right to a healthy and clean environment); *Urgenda Foundation v. the Netherlands*, Judgment, Dutch Supreme Court (Hoge Raad), No.

122. It is self-evident that climate change and environmental degradation implicate and infringe the right to a healthy environment.

4. *Right to health*

123. The right to health is codified in various international instruments and treaties, including the following:

a. Universal Declaration of Human Rights: "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family."[262]

b. International Covenant on Economic, Social and Cultural Rights ("ICESCR"): "1. The States Parties to the present Covenant recognize the right of everyone to the enjoyment of the highest attainable standard of physical and mental health. 2. The steps to be taken by the States Parties to the present Covenant to achieve the full realization of this right shall include those necessary for: . . . (b) The improvement of all aspects of environmental and industrial hygiene."[263]

c. Convention on the Rights of the Child: "States Parties recognize the right of the child to the enjoyment of the highest attainable standard of health."[264]

d. African Charter on Human and Peoples' Rights: "Every individual shall have the right to enjoy the best attainable state of physical and mental health that they are able to achieve."[265]

e. European Social Charter: "Everyone has the right to benefit from any measures enabling him to enjoy the highest possible standard of health attainable."[266]

124. The U.N. Committee on International Economic, Social and Cultural Rights—i.e., the treaty body charged with monitoring the implementation of the ICESCR—has provided extensive guidance on the right to health. In particular, the Committee has clarified that the right to health encompasses a "wide range of socio-economic factors that promote conditions in which people can lead a healthy life, and

19/00135, ECLI:NL:HR:2019:2006 (20 December 2020), ¶ 5.7.1. ("the Netherlands had an obligation 'to do 'its part' in order to prevent dangerous climate change, even if it is a global problem'"); *Future Generations v. Ministry of the Environment*, Decision Supreme Court of Colombia, No. 11001 22 03 000 2018 00319 00 (5 April 2018); *Gloucester Resources Limited v. Minister of Planning*, Decision, New South Wales Land and Environment Court, [2019] NSWLEC 7 (8 February 2019), ¶ 698.

262 Universal Declaration of Human Rights (1948), Art. 25.

263 International Covenant on Economic, Social and Cultural Rights (1966), Art. 12.

264 Convention on the Rights of the Child, 1577 UNTS 3 (20 November 1989), Art. 24.

265 African Charter on Human and People's Rights (1981), Art. 16.

266 European Social Charter (1961), Art. 11.

extends to the underlying determinants of health, such as . . . access to safe and potable water and adequate sanitation . . . and a healthy environment."[267]

125. The right to health entails corresponding obligations for States, which obligations encompass duties related to the environment. For example, in order to fulfill their obligation to *respect* the right to health, States should "refrain from unlawfully polluting air, water and soil, e.g. through industrial waste from State-owned facilities, from using or testing nuclear, biological or chemical weapons if such testing results in the release of substances harmful to human health."[268] Pursuant to the obligation to *protect* the right to health, States are in violation if they "fail . . . to enact or enforce laws to prevent the pollution of water, air and soil by extractive and manufacturing industries."[269] And pursuant to the obligation to *fulfil* the right to health, States are required to "adopt measures against environmental and occupational health hazards and against any other threat as demonstrated by epidemiological data," including "national policies aimed at reducing and eliminating pollution of air, water and soil, including pollution by heavy metals such as lead from gasoline."[270]

126. Consistent with these principles, international bodies,[271] domestic courts,[272] and tribunals have recognized that the guarantee of a right to health includes an obligation by States to protect people from the impacts of environmental degradation.

5. *Right to private and family life*

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[267] U.N. Committee on Economic, Social, and Cultural Rights, *General Comment No. 14, The right to the highest attainable standard of health (article 12 of the International Covenant on Economic, Social and Cultural Rights)* (2000), ¶ 4. *See also id.* at ¶ 11.

[268] U.N. Committee on Economic, Social, and Cultural Rights, *General Comment No. 14, The right to the highest attainable standard of health (article 12 of the International Covenant on Economic, Social and Cultural Rights)* (2000), ¶ 34.

[269] U.N. Committee on Economic, Social, and Cultural Rights, *General Comment No. 14, The right to the highest attainable standard of health (article 12 of the International Covenant on Economic, Social and Cultural Rights)* (2000), ¶ 51.

[270] U.N. Committee on Economic, Social, and Cultural Rights, *General Comment No. 14, The right to the highest attainable standard of health (article 12 of the International Covenant on Economic, Social and Cultural Rights)* (2000), ¶ 36.

[271] *See, e.g.*, *Social and Economic Rights Action Centre (SERAC) & Centre for Economic and Social Rights (CESCR) v. Nigeria*, Communication 115/96, African Commission on Human and Peoples' Rights [Afr. Comm'n H.P.R.] (27 October 2001); *Marangopoulos Found. for Human Rights v. Greece*, Complaint No. 30/2005, European Committee of Social Rights, Case Document No. 1 (23 March 2005; registered 4 April 2005).

[272] *See, e.g.*, *Gbemre v. Shell Petroleum Development Company Nigeria Limited and Others*, Judgment, suit FHC/B/CS/53/05 (14 November 2005).

127. The right to private and family life is recognized in various treaties, including the ICCPR and the European Convention on Human Rights. Article 17 of the ICCPR codifies this right as follows:

> 1. No one shall be subjected to arbitrary or unlawful interference with his privacy, family, home or correspondence, nor to unlawful attacks on his honour and reputation.
>
> 2. Everyone has the right to the protection of the law against such interference or attacks.[273]

128. The right to private and family life has been interpreted broadly, so as to include varying conceptions of the family and home in different cultures. In this respect, the Human Rights Committee has clarified that "[t]he term 'home' in English, 'manzel' in Arabic, 'zhùzhái' in Chinese, 'domicile' in French, 'zhilische' in Russian and 'domicilio' in Spanish, as used in article 17 of the Covenant, is to be understood to indicate the place where a person resides or carries out his usual occupation."[274]

129. Importantly, the right to private and family life entails a corresponding obligation on the part of the State:

> States parties must prevent interference with a person's privacy, family or home that arises from conduct not attributable to the State, at least where such interference is foreseeable and serious.[275]

130. The Committee has expressly recognized the interconnection between the right to private and family life and the environment. Specifically, in May 2019, eight Australian nationals—all of whom were residents of the Torres Strait region—submitted a complaint alleging that Australia violated their rights as well as the rights of their children as protected by the ICCPR.[276] The authors of the complaint noted that the indigenous peoples of the Torres Strait Islands are among the most vulnerable to the impacts of climate change. They alleged that Australia had failed to implement adaptation measures to protect the habitability of the islands against the effects of climate change, and particularly sea level rise, and that Australia has failed to mitigate the impact of climate change, including by failing to reduce its greenhouse gas emissions. With respect to their rights under the ICCPR, the authors of the complaint argued that climate change had already affected their

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[273] ICCPR (1966), Art. 17.
[274] U.N. Human Rights Committee, *CCPR General Comment No. 16: Article 17 (Right to Privacy), The Right to Respect of Privacy, Family, Home and Correspondence, and Protection of Honour and Reputation* (1988), ¶ 5.
[275] U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022), ¶ 8.9.
[276] U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022).

private, family and home life, because they faced the prospect of having to abandon their homes due to sea level rise.

131. In July 2022, the Committee issued its decision,[277] and observed that the authors had already sought relief in the domestic judicial system, but that "the highest court in Australia has ruled that state organs do not owe a duty of care for failing to regulate environmental harm."[278] However, the Committee found that Australia "[wa]s and has been in recent decades among the countries in which large amounts of greenhouse gas emissions have been produced."[279] The Committee then reasoned that Australia had violated the authors' right to private and family life, reasoning as follows:

> The Committee considers that when climate change impacts – including environmental degradation on traditional [indigenous] lands in communities where subsistence is highly dependent on available natural resources and where alternative means of subsistence and humanitarian aid are unavailable – have direct repercussions on the right to one's home, and the adverse consequences of those impacts are serious because of their intensity or duration and the physical or mental harm that they cause, then the degradation of the environment may adversely affect the well-being of individuals and constitute foreseeable and serious violations of private and family life and the home. The Committee concludes that the information made available to it indicates that by failing to discharge its positive obligation to implement adequate adaptation measures to protect the authors' home, private life and family, the State party violated the authors' rights under article 17 of the Covenant.[280]

132. Thus, the obligation to protect private and family life may be violated by States that fail to adequately address the causes and effects of climate change.

6. *Right to seek, receive, and impart information*

133. International treaty law codifies the right to seek, receive, and impart information. For example, Article 19 of the ICCPR provides as follows:

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277 U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022).
278 U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022).
279 U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022).
280 U.N. Human Rights Committee, *Views adopted by the Committee under article 5(4) of the Optional Protocol, concerning communication No. 3624/2019*, CCPR/C/135/D/3624/2019 (21 July 2022), ¶ 8.12.

> 1. Everyone shall have the right to hold opinions without interference.
>
> 2. Everyone shall have the right to freedom of expression; this right shall include freedom to seek, receive and impart information and ideas of all kinds, regardless of frontiers, either orally, in writing or in print, in the form of art, or through any other media of his choice.[281]

134. International instruments have recognized that these rights are inherently linked to States' duties in respect of climate change and the protection of the environment.[282] For example, the Rio Declaration on Environment and Development emphasizes that:

> States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies.
>
> Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective

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[281] ICCPR (1966), Art. 19. *See also* UDHR (1948), Art. 19 ("Everyone has the right to freedom of opinion and expression; this right includes freedom to hold opinions without interference and to seek, receive and impart information and ideas through any media and regardless of frontiers"), Art. 27 ("1. Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits.").

[282] *See, e.g.*, *Stockholm Declaration of the United Nations Conference on the Human Environment*, in *Report of the United Nations Conference on the Human Environment*, A/CONF.48/14/Rev. 1 (1972), Principle 19 ("Education in environmental matters, for the younger generation as well as adults, giving due consideration to the under-privileged, is essential in order to broaden the basis for an enlightened opinion and responsible conduct by individuals, enterprises and communities in protecting and improving the environment in its full human dimension. It is also essential that mass media of communications avoid contributing to the deterioration of the environment, but, on the contrary, disseminate information of an educational nature, on the need to protect and improve the environment in order to enable man to develop in every respect"); *see also* Protocol on Strategic Environmental Assessment to the Espoo Convention ("**Kyiv (SEA) Protocol**") (2003), Art. 8(1) ("1. Each Party shall ensure early, timely and effective opportunities for public participation, when all options are open, in the strategic environmental assessment of plans and programmes.").

access to judicial and administrative proceedings, including redress and remedy, shall be provided.[283]

135. In this respect, 46 States have ratified the Aarhus Convention (discussed above), which codifies a series of binding obligations to provide information on issues related to the environment.[284]

136. Consistent with these international principles, domestic courts have issued rulings requiring the disclosure of information on the effects of climate change and States' activities related thereto.[285]

7. *Right to effective remedy*

137. A critical element of human rights law is the right to an effective remedy. This right is recognized in many international instruments and treaties, including the Universal Declaration on Human Rights and the ICCPR.[286]

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[283] Rio Declaration (1992), Principles 9–10.

[284] *See* Aarhus Convention (25 June 1998), Art. 1 ("In order to contribute to the protection of the right of every person of present and future generations to live in an environment adequate to his or her health and well-being, each Party shall guarantee the rights of access to information, public participation in decision-making, and access to justice in environmental matters in accordance with the provisions of this Convention"), Art. 2 ("Environmental information" means any information in written, visual, aural, electronic or any other material form on: (a) The state of elements of the environment, such as air and atmosphere, water, soil, land, landscape and natural sites, biological diversity and its components, including genetically modified organisms, and the interaction among these elements; (b) Factors, such as substances, energy, noise and radiation, and activities or measures, including administrative measures, environmental agreements, policies, legislation, plans and programmes, affecting or likely to affect the elements of the environment within the scope of subparagraph (a) above, and cost-benefit and other economic analyses and assumptions used in environmental decision-making; (c) The state of human health and safety, conditions of human life, cultural sites and built structures, inasmuch as they are or may be affected by the state of the elements of the environment or, through these elements, by the factors, activities or measures referred to in subparagraph (b) above"), Art. 3(3) ("Each Party shall promote environmental education and environmental awareness among the public, especially on how to obtain access to information, to participate in decision-making and to obtain access to justice in environmental matters.").

[285] *See, e.g.*, *Greenpeace France v. France*, Case No. 20216119 (16 December 2021); *(B.U.N.D.) e.V. v. Minister for Commerce and Labor on behalf of Federal Republic of Germany*, Order, [2006] VG 10 A 215.04 (2 March 2006) (rejecting the government's argument that information on German export credit activities did not constitute "environmental information"); *Natural Resources Defense Council v. EPA*, Case No. 1:18-cv-11227 (2d Cir. 2018).

[286] *See, e.g.*, Universal Declaration of Human Rights (1948), Art. 8 ("Everyone has the right to an effective remedy by the competent national tribunals for acts violating the fundamental rights granted him by the constitution or by law."); International Covenant on Civil and Political Rights (adopted 16 December 1966; entered into force 23 March 1976), 999 UNTS 171, Art. 2 (outlining the ICCPR's provision of the right to an effective remedy); International Convention on the Elimination of All Forms of Racial Discrimination (21 December 1965), Art. 6 ("States Parties shall assure to everyone within their jurisdiction effective protection and remedies, through the competent national tribunals and other State institutions, against any acts of

racial discrimination which violate his human rights and fundamental freedoms contrary to this Convention, as well as the right to seek from such tribunals just and adequate reparation or satisfaction for any damage suffered as a result of such discrimination."); U.N. Convention against Torture (10 December 1984), Art. 14 ("1. Each State Party shall ensure in its legal system that the victim of an act of torture obtains redress and has an enforceable right to fair and adequate compensation, including the means for as full rehabilitation as possible. In the event of the death of the victim as a result of an act of torture, his dependants shall be entitled to compensation. 2. Nothing in this article shall affect any right of the victim or other persons to compensation which may exist under national law."); Rome Statute, Art. 68 (titled "Protection of the victims and witnesses and their participation in the proceedings"); *id.*, Art. 75 (titled "Reparations to victims"); Hague Convention IV Respecting the Laws and Customs of War on Land (18 October 1907), Art. 3 ("A belligerent party which violates the provisions of the said Regulations shall, if the case demands, be liable to pay compensation. It shall be responsible for all acts committed by persons forming part of its armed forces."); Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I) (8 June 1977), Art. 91 ("A Party to the conflict which violates the provisions of the Conventions or of this Protocol shall, if the case demands, be liable to pay compensation. It shall be responsible for all acts committed by persons forming part of its armed forces."); African Charter on Human and People's Rights (1981), Art. 7 ("Every individual shall have the right to have his cause heard. This comprises: The right to an appeal to competent national organs against acts of violating his fundamental rights as recognized and guaranteed by conventions, laws, regulations and customs in force; The right to be presumed innocent until proved guilty by a competent court or tribunal; The right to defence, including the right to be defended by counsel of his choice; The right to be tried within a reasonable time by an impartial court or tribunal. No one may be condemned for an act or omission which did not constitute a legally punishable offence at the time it was committed. No penalty may be inflicted for an offence for which no provision was made at the time it was committed. Punishment is personal and can be imposed only on the offender."); American Convention on Human Rights (22 November 1969), 1144 UNTS 123, Art. 25 ("1. Everyone has the right to simple and prompt recourse, or any other effective recourse, to a competent court or tribunal for protection against acts that violate his fundamental rights recognized by the constitution or laws of the state concerned or by this Convention, even though such violation may have been committed by persons acting in the course of their official duties. 2. The States Parties undertake: a. to ensure that any person claiming such remedy shall have his rights determined by the competent authority provided for by the legal system of the state; b. to develop the possibilities of judicial remedy; and c. to ensure that the competent authorities shall enforce such remedies when granted."); Convention for the Protection of Human Rights and Fundamental Freedoms (European Convention on Human Rights, as amended) (2021), Art. 13 ("Right to an effective remedy [—] Everyone whose rights and freedoms as set forth in this Convention are violated shall have an effective remedy before a national authority notwithstanding that the violation has been committed by persons acting in an official capacity."); Charter of Fundamental Rights of the European Union (2000), Art. 47 ("Everyone whose rights and freedoms guaranteed by the law of the Union are violated has the right to an effective remedy before a tribunal in compliance with the conditions laid down in this Article. Everyone is entitled to a fair and public hearing within a reasonable time by an independent and impartial tribunal previously established by law. Everyone shall have the possibility of being advised, defended and represented. Legal aid shall be made available to those who lack sufficient resources in so far as such aid is necessary to ensure effective access to justice."); *see also* Declaration of Basic Principles and Guidelines on the Right to a Remedy and Reparation for Victims of Gross Violations of International Human Rights Law and Serious Violations of International Humanitarian Law (16 December 2005) and U.N. General Assembly, *Basic Principles and Guidelines on the Right to a Remedy and Reparation for Victims of Gross Violations of International Human Rights Law and Serious Violations of International Humanitarian Law*, Res. 60/147 (16 December 2005), by which the Assembly adopted the recommended text ("Scope of Obligation: 3. The

138. This right—based upon the general principle of *ubi ius ibi remedium* ("for every wrong, the law provides a remedy")—applies in the context of climate change.[287] The OHCHR summarized the application as follows:

> The Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, and other human rights instruments require States to guarantee effective remedies for human rights violations. Climate change and its impacts, including sea level rise, extreme weather events, and droughts have already inflicted human rights harms on millions of people. For States and communities on the frontline, survival itself is at stake. **Those affected, now and in the future, must have access to meaningful remedies including judicial and other redress mechanisms**.

139. The scope of the obligation is broad:

> The obligations of States in the context of climate change and other environmental harms extend to all rights-holders and to harm that occurs both inside and beyond boundaries. States should be accountable to rights-holders for their contributions to climate change including for failure to adequately regulate the emissions of businesses under their jurisdiction regardless of where such emissions or their harms actually occur.[288]

140. Further, States are required to take adequate measures to ensure effective remedies against private actors—e.g., businesses and industries that cause or contribute to environmental harm.[289]

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obligation to respect, ensure respect for and implement international human rights law and international humanitarian law as provided for under the respective bodies of law, includes, inter alia, the duty to: (a) Take appropriate legislative and administrative and other appropriate measures to prevent violations; (b) Investigate violations effectively, promptly, thoroughly and impartially and, where appropriate, take action against those allegedly responsible in accordance with domestic and international law; (c) Provide those who claim to be victims of a human rights or humanitarian law violation with equal and effective access to justice, as described below, irrespective of who may ultimately be the bearer of responsibility for the violation; and (d) Provide effective remedies to victims, including reparation, as described below.").

[287] *Understanding Human Rights and Climate Change*, Submission of the Office of the High Commissioner for Human Rights to the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (2021).

[288] *Understanding Human Rights and Climate Change*, Submission of the Office of the High Commissioner for Human Rights to the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (2021), ¶ 3.

[289] *Understanding Human Rights and Climate Change*, Submission of the Office of the High Commissioner for Human Rights to the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (2021), ¶ 8.

C. Intergenerational Equities

141. International law recognizes that environmental protection is an obligation owed to present and future generations alike. Thus, intergenerational equity requires that the development of a State should not compromise the needs and aspirations of future generations. In this sense, the principle of intergenerational equity "defines the rights and obligations of present and future generations with respect to the use and enjoyment of natural and cultural resources, inherited by the present generation and to be passed on to future generations in no worse condition than received."[290]

142. The notion of intergenerational equity has been extensively developed in international instruments related to environmental conservation and climate change[291]. For instance, the Stockholm Declaration establishes that mankind "has a solemn responsibility to protect and improve the environment for present and future generations" for which natural resources, including air, water, land, flora and fauna must be preserved for their benefit "through careful planning or management."[292] Likewise, the Rio Declaration recognizes, in its Principle 3, that "the right to development should be exercised in a manner which equitably meets the developmental and environmental needs of present and future generations."[293]

143. In the present section, relevant aspects of the principle of intergenerational equity will be covered, namely: 1) intergenerational equity and sustainable development; 2) intragenerational and intergenerational equity; and 3) the rights of future generations.

1. *Intergenerational Equity and Sustainable Development*

144. According to the Bruntland Report, sustainable development refers to "the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own

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[290] Catherine Redgwell, *Principles and Emerging Norms in International Law: Intra- and Inter-generational Equity*, in PART III CLIMATE CHANGE—PRINCIPLES AND EMERGING NORMS CONCEPTS IN INTERNATIONAL LAW, in CH. 9, THE OXFORD HANDBOOK OF INTERNATIONAL CLIMATE CHANGE LAW (2009).

[291] See, *inter alia*, International Convention for the Regulation of Whaling, 2 UST 720, 59 Stat. 1716, T.I.A.S. 1849, [57 UNTS 73] (1946), Preamble; Convention Concerning the Protection of the World Cultural and Natural Heritage, 27 UST 37, TIAS 8226, [1037 UNTS 151] (1972), Art. 4; Convention on International Trade in Endangered Species of Wild Fauna and Flora, 993 UNTS 243 (1975), Preamble; Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention), 38 ILM 517, [25 I.L.M. 1396] (1999), Art. 1; and Escazú Agreement (4 March 2018), Arts. 1 and 3(g).

[292] *Stockholm Declaration of the United Nations Conference on the Human Environment*, in *Report of the United Nations Conference on the Human Environment*, A/CONF.48/14/Rev. 1 (1972), Principles 1 and 3.

[293] Rio Declaration (1992), Principle 3.

needs."[294] It is a "process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs" which has three core pillars (environmental, social and economic).[295]

145. Sustainable development and intergenerational equity are deeply interlinked. If States are to protect the environment to guarantee the rights of generations to come, then their development model cannot be one based on the exploitation of finite natural resources beyond planetary boundaries. Therefore, as Weiss argues, "the procedural and substantive duties that have been articulated to ensure sustainable development may be regarded as implementing the principle of intergenerational equity."[296] This is also supported by the phrasing of the Stockholm and Rio Declarations noted above. Additionally, in its universal recognition of the right to a healthy environment, the United Nations General Assembly has also recognized that "sustainable development, in its three dimensions (social, economic and environmental), and the protection of the environment, including ecosystems, contribute to and promote human well-being and the full enjoyment of all human rights, for present and future generations."[297] Consequently, sustainable development is a condition for achieving intergenerational equity.

2. *Intra-generational Equity and Intergenerational Equity*

146. Intra-generational equity refers to equity in the distribution of the benefits and burdens of development within the existing generations of humanity. In this sense, Principle 5 of the World Declaration on the Environmental Rule of Law provides that "there shall be a fair and equitable access to and sharing of the benefits of ecosystem services. In the event of pollution, there shall be a fair and equitable sharing of pollution burdens. Natural resources shall be managed so that that they are used as economically as achievable, through high efficiency and avoidance of waste."[298]

147. On this matter, the International Law Association's ("**ILA**") Legal Principles Relating to Climate Change establish that "present generations in developing States have a legitimate expectation of equitable access to sustainable development. This recognizes that to the extent that per capita emissions in

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[294] *Report of the World Commission on Environment and Development: Our Common Future*, A/42/427 (1987), ¶ 27.
[295] Ibid, ¶¶ 27–30.
[296] Edith Brown Weiss, *Intergenerational Equity*, in MAX PLANCK ENCYCLOPEDIAS OF INTERNATIONAL LAW (2009).
[297] U.N. General Assembly, *The Human Right to a Clean, Healthy and Sustainable Environment*, A/76/L.75 (26 July 2022), p. 2.
[298] IUCN, *World Declaration on the Environmental Rule of Law* (2016), Principle 5.

developing countries are still low, these will grow, within reason and in a sustainable manner, to meet their social and development needs."[299] When applied to inter-State relations, it has been argued that the CBDR principle is in fact an expression of intra-generational equity.[300] Within States, intra-generational equity has been linked to the eradication of poverty, and more broadly, to "equal access to common resources to be shared by humankind over time, rather than just the distribution of private property."[301]

3. *Rights of Future Generations*

148. The rights of future generations, including in respect of the environment, are also recognized in treaty and in case law.

a. Treaty Law

149. Several international treaties recognize that environmental preservation is an obligation owed to present and future generations alike. The preamble of the Convention on Biological Diversity states the sustainable use of biological diversity must occur "in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations."[302] For its part, the World Heritage Convention recognizes that "the duty of ensuring the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage referred to in Articles 1 and 2 and situated on its territory, belongs primarily to that State . . . ."[303] Moreover, Article 2.5(c) of the U.N. Economic Commission for Europe ("**UNECE**") Convention on the Protection and Use of Transboundary Watercourses and International Lakes provides that "water resources shall be managed so that the needs of the present generation are met without compromising the ability of future generations to meet their own needs."[304]

150. Intergenerational equity is also present in the international treaties pertaining to climate change. The UNFCCC provides that States Parties should "protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated

[299] ILA, *Report of the ILA's Committee on Legal Principles Relating to Climate Change* (2014), Draft Art. 4.
[300] *See* Catherine Redgwell, *Principles and Emerging Norms in International Law: Intra- and Inter-generational Equity*, *in* PART III CLIMATE CHANGE—PRINCIPLES AND EMERGING NORMS CONCEPTS IN INTERNATIONAL LAW, *in* CH. 9, THE OXFORD HANDBOOK OF INTERNATIONAL CLIMATE CHANGE LAW (2009).
[301] U.N. Secretary General, *Report on the Intergenerational solidarity and the needs of future generations*, A/68/322, (15 August 2013), ¶ 18.
[302] CBD (1992), preamble.
[303] World Heritage Convention (1972), Art. 4
[304] Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992), Art. 2(5)(c).

responsibilities and respective capabilities."[305] More specifically, the Paris Agreement provides that, in taking action to combat climate change, States should "respect, promote and take into account their respective obligations relating to human rights ... and intergenerational equity."[306]

(i) Convention of the Rights of the Child

151. The U.N. Convention on the Rights of the Child[307] ("**UNCRC**") is widely ratified.[308] As one author noted, the UNCRC is "probably the first universal treaty to include several references to the environment."[309] The UNCRC's treaty body is the CRC Committee. Made up of eighteen independent experts, the Committee "monitors implementation of the [UNCRC and its Optional Protocols] by its States parties."[310] UNICEF (the United Nations Children's Fund) is the primary international agency tasked with protecting children's rights. Climate change's impacts on children are dire, and as one set of authors wrote, "the effect of climate change on the rights of children to optimal survival and development is immeasurable and requires a concerted international effort to reverse its impending catastrophic consequences."[311] Particularly relevant to a discussion of climate change in context of the UNCRC are the following:[312]

a. Article 2: the right to freedom from discrimination;

b. Article 3: the principle that all institutions should work with the best interests of the child as "a primary consideration;"

c. Article 6: the right to life, survival, and development;

d. Article 12: the right to express one's views and to have those views be given "due weight in accordance with the age and maturity of the child;" and

e. Article 24: the right to the "highest attainable standard of health."

152. Notably, the Committee has identified four of these five articles – Articles 2, 3, 6, and 12 – as lenses through which the entire UNCRC should be viewed.[313] Finally,

[305] UNFCCC (1992), Art. 3.
[306] Paris Agreement (2015), preamble.
[307] Convention on the Rights of the Child, 1577 UNTS 3 (20 November 1989).
[308] *See* U.N. Office of the High Commissioner for Human Rights, *U.N. Treaty Body Database: Ratification Status for CRC - Convention on the Rights of the Child*, U.N. HUM. RTS. TREATY BODIES.
[309] Susana Sanz-Caballero, *Children's Rights in a Changing Climate: A Perspective from the United Nations Convention on the Rights of the Child*, 13 ETHICS IN SCI. & ENV'T POL. 1, 4 (2013), *supra* note 362, p. 3.
[310] U.N. Office of the High Commissioner for Human Rights, *Committee on the Rights of the Child*.
[311] Jeffrey L. Goldhagen et al., *Rights, Justice, and Equity: A Global Agenda for Child Health and Wellbeing*, 4 LANCET CHILD ADOLESCENT HEALTH 80, 85 (2020).
[312] Convention on the Rights of the Child, 1577 UNTS 3 (20 November 1989).
[313] U.N. Committee on the Rights of the Child, *General Comment No. 5 (2003): General measures of implementation of the Convention on the Rights of the Child (arts. 4, 42 and 44, para. 6)*, CRC/GC/2003/5 (2003), ¶ 12.

it is also worth stating that this list is by no means exhaustive. Various sources have emphasized other articles as particularly relevant for climate change.[314] What's more, UNICEF has stated that "[b]ecause of the inter-connected and inter-related nature of rights, ... virtually *all* children's rights may be affected by the climate crisis, potentially impacting the effective implementation of the [UNCRC] as a whole" (emphasis added).[315]

(a) Article 2: The Right to Freedom from Discrimination

153. Article 2 is closely tied to other treaties and also presents unique climate change-related claims, so this section is split into two subsections accordingly. The first discusses Article 2 and its requirements writ large, and the second focuses on Article 2's relationship with climate change.

154. Article 2's Meaning Writ Large. Article 2 of the UNCRC sets forth a prohibition on discrimination on a variety of bases. The text is "broadly comparable" to antidiscrimination provisions in previous human rights treaties, such as "the Universal Declaration of Human Rights [('UDHR')], the International Covenant on Civil and Political Rights [('ICCPR')], and the International Covenant on Economic, Social and Cultural Rights [('ICESCR')]."[316] Article 2 is "directly justiciable and may be invoked by victims of discrimination as an immediately realizable right," though this fact may be tempered by the UNCRC's allowance of gradual realization of rights.[317]

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[314] *See, e.g.*, UNICEF, THE CHALLENGES OF CLIMATE CHANGE: CHILDREN ON THE FRONT LINE (2014), pp. 48-49 (hereinafter "**UNICEF, CHALLENGES**") (listing and providing explanations of climate change's connection with fourteen different Articles); UNICEF, THE CLIMATE CRISIS IS A CHILD RIGHTS CRISIS: INTRODUCING THE CHILDREN'S CLIMATE RISK INDEX (2012), p. 111 (hereinafter "**UNICEF, CLIMATE CRISIS**") (reporting a bit shorter of a list than the source *supra*); Katharina Ruppel-Schlichting et al., *Climate Change and Children's Rights: An International Law Perspective*, *in* CLIMATE CHANGE: INTERNATIONAL LAW AND GLOBAL GOVERNANCE 349, 364 (Oliver C. Ruppel et al. eds., 2013) (listing Articles 2, 3, 6, 12, 24, and 29).

[315] UNICEF, CLIMATE CRISIS, *supra* note 314, p. 111 (emphasis modified).

[316] Gerison Lansdown, *Article 2: The Right to Non-Discrimination*, *in* MONITORING STATE COMPLIANCE WITH THE UN CONVENTION ON THE RIGHTS OF THE CHILD: AN ANALYSIS OF ATTRIBUTES 11, 12 (Ziba Vaghri et al. eds., 2022).

Notably, the UNCRC version "potentially strengthens the jurisdictional accountability of States Parties by removing the [ICCPR provision] that individuals must be living within the territory and subject to the state jurisdiction and requires only that they are within the jurisdiction of the state." *Id.* In practice, "[w]hat matters for the State's jurisdiction is the authority or responsibility *de facto* rather than *de jure* of the State Party." *See* Samantha Besson, *The Principle of Non-Discrimination in the Convention on the Rights of the Child*, 13 INT'L J. CHILDREN'S RTS. 433, 450 (2005).

[317] Samantha Besson, *The Principle of Non-Discrimination in the Convention on the Rights of the Child*, 13 INT'L J. CHILDREN'S RTS. 433, 450 (2005), *supra* note 316, pp. 454–455.

155. This article "requires States actively to identify individual children and groups of children the recognition and realization of whose rights may demand special measures."[318]

156. One author described Article 2 as "foresee[ing] two kinds of obligations which complement each other": "duties of respect" and "duties of result."[319] Duties of respect are "rather passive or negative," forbidding the State from discriminatory policies, while duties of result "go further and are more active or positive. . . . They imply that the State take all necessary measures to ensure for each child a discrimination-free enjoyment of all Convention rights."[320] What's more, States may need to take action beyond mere legislation; antidiscrimination requirements may necessitate "administration and resource allocation, as well as educational measures to change attitudes in the media and the private sphere."[321]

157. Article 2 and Climate Change. Article 2, the UNCRC's antidiscrimination provision, can be construed as protecting children from the effects of climate change on at least two bases. First, due to climate change's unequal impacts based on various demographics, such as disability, States' failure to address climate change results in disparate treatment based on these classifications. Second, inaction on climate change violates a still-emerging legal theory: the idea that Article 2 protects children from discrimination on the basis of their status *as* children.

158. Climate change's impacts will not be felt evenly among children worldwide. Rather, "climate change will increasingly have a disproportionate effect on the rights of specific groups of vulnerable children, including displaced children, children living in poverty, indigenous children, and children with developmental disabilities."[322] Additionally, within countries, different geographical areas are expected to experience different levels of climate change.[323] Several of these various categories (e.g., children with disabilities) are explicitly mentioned in Article 2.[324] Due to those various categorizations alone, the unequal burden in climate effects means that a failure by a state to work to combat climate change

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[318] U.N. Committee on the Rights of the Child, *General Comment No. 5 (2003): General measures of implementation of the Convention on the Rights of the Child (arts. 4, 42 and 44, para. 6)*, CRC/GC/2003/5 (2003), *supra* note 313, ¶ 12.
[319] Samantha Besson, *The Principle of Non-Discrimination in the Convention on the Rights of the Child*, 13 INT'L J. CHILDREN'S RTS. 433, 450 (2005), *supra* note 317, p. 454 (emphasis omitted).
[320] *Id.*
[321] *Id.*
[322] Jeffrey L. Goldhagen et al., *Rights, Justice, and Equity: A Global Agenda for Child Health and Wellbeing*, 4 LANCET CHILD ADOLESCENT HEALTH 80, 85 (2020), *supra* note 311, p. 85.
[323] *See* UNICEF, CLIMATE CRISIS, *supra* note 314, p. 12 (mapping locations expected to have "[o]verlapping" climate change effects).
[324] Convention on the Rights of the Child, 1577 UNTS 3 (20 November 1989), Art. 2.

can be considered an acquiescence to discriminatory policies, in direct violation of Article 2 of the UNCRC.

159. One currently developing framework is the idea that Article 2 protects children from discrimination based on their status *as* children. This idea, as of right now, "still [has] limited explicit recognition at [the] national and international level."[325] Notably, however, a climate-change-focused case[326] currently pending before the ECtHR raises the claim of discrimination against children – likely "the first time that youth has been invoked as a ground for discrimination at the level of international human rights law."[327] It is also worth noting that back in 2014, UNICEF stated that the right to non-discrimination under Article 2 "can be threatened if decisions do not recognize the special needs of children."[328]

160. Within the context of Article 2, such a claim would fall under the ban on discrimination on the basis of some "other status." The argument would be that, since "there is ample evidence that children are more prone to the harmful health and other negative effects of climate change than adults,"[329] policies that exacerbate climate change are therefore discriminatory against children. Indeed, even back in 2014, UNICEF reported that "[e]ven leaving aside natural disasters, children are already suffering most from the adverse health consequences of a warmer world, accounting for up to four in five of all illnesses, injuries and deaths attributable to climate change."[330]

(b) Article 3: The Best Interests of the Child

161. Due to differing opinions over the proper interpretation of Article 3, this section is split into two subsections: one about the Article itself and another about the Article's intersection with climate change.

162. Interpretation of Article 3. Article 3 requires that "[i]n all actions concerning children, whether undertaken by public or private social welfare institutions, courts of law, administrative authorities or legislative bodies, the best interests of the child shall be a primary consideration."[331] The Committee has stated that "public or private social welfare institutions" should be interpreted "to mean all

[325] Aoife Daly et al., *UN Convention on the Rights of the Child, Article 2 and Discrimination on the Basis of Childhood: The CRC Paradox?*, 91 NORDIC J. INT'L L. 419, 420 (2022).
[326] *Agostinho v. Portugal and 32 Other States*, App. No. 39371/20 (currently pending before the Grand Chamber of the Eur. Ct. of Hum. Rts.).
[327] Aoife Daly, *Climate Competence: Youth Climate Activism and Its Impact on International Human Rights Law*, 22 HUM. RTS. L. REV., p. 19 (2022).
[328] UNICEF, CHALLENGES, *supra* note 314, p. 48.
[329] Karin Arts, *Children's Rights and Climate Change*, *in* CHILDREN'S RIGHTS AND SUSTAINABLE DEVELOPMENT: INTERPRETING THE UNCRC FOR FUTURE GENERATIONS (Claire Fenton-Glynn ed., 2019), pp. 216, 218.
[330] UNICEF, CHALLENGES, *supra* note 314, p. 1. For more information on climate change's disproportionate impact on children, see generally *id.*
[331] Convention on the Rights of the Child, 1577 UNTS 3 (20 November 1989).

institutions whose work and decisions impact on children and the realization of their rights[,]" including institutions whose work impacts the environment.[332] The definition of "best interests" may be intentionally vague.[333] Finally, the Committee has stated that "[t]he words 'shall be' place a strong legal obligation on States and mean that States may not exercise discretion as to whether children's best interests" should be taken into account.[334]

163. The Committee has stated that the right presented by Article 3 is a "threefold concept," composed of a "substantive right," a "fundamental, interpretative legal principle," and a "rule of procedure."[335] The substantive right is the right of children to have their best interests "assessed and taken as a primary consideration," and the legal principle states that "[i]f a legal provision is open to more than one interpretation, the interpretation which most effectively serves the child's best interests should be chosen."[336] Finally, the rule of procedure requires, at least in part, that decision-making entities evaluate their potential choices' impacts on children.[337]

164. That being said, at least some scholars have pushed back on the first of those three aspects: "'a plain reading of the text does not support the view that Article 3(1) [CRC] contains a right,' nor a directly applicable right (self-executing) that can be invoked before a court."[338] One such scholar explained the correct application as follows:

> [B]est interests need to be assessed by decision-makers as part of a process where rules of procedure will be applied so that the best interest principle acts as one of the foundations for a substantive

[332] U.N. Committee on the Rights of the Child, *General comment No. 14 (2013) on the right of the child to have his or her best interests taken as a primary consideration (art. 3, para. 1)*, CRC/C/GC/14 (29 May 2013), ¶ 26.
[333] *See generally* Francesca Ippolito, *The Best Interests of the Child: Another String to the Environmental and Climate Protection Bow?*, 89 QUESTIONS INT'L L. 7, 7-9 (2022) (discussing the term "best interests of the child").
[334] U.N. Committee on the Rights of the Child, *General comment No. 14 (2013) on the right of the child to have his or her best interests taken as a primary consideration (art. 3, para. 1)*, CRC/C/GC/14 (29 May 2013), *supra* note 332, ¶ 36.
[335] U.N. Committee on the Rights of the Child, *General comment No. 14 (2013) on the right of the child to have his or her best interests taken as a primary consideration (art. 3, para. 1)*, CRC/C/GC/14 (29 May 2013), *supra* note 332, ¶ 6.
[336] *Id.*,¶¶ 6(a)–(b)
[337] *Id.*, ¶ 6(c).
[338] Francesca Ippolito, *The Best Interests of the Child: Another String to the Environmental and Climate Protection Bow?*, 89 QUESTIONS INT'L L. 7 (2022), *supra* note 333, pp. 9-10 (footnote omitted) (quoting Ursula Kilkelly, *The Best Interests of the Child: A Gateway to Children's Rights?*, *in* IMPLEMENTING ARTICLE 3 OF THE UNITED NATIONS CONVENTION ON THE RIGHTS OF THE CHILD: BEST INTERESTS, WELFARE AND WELL-BEING (Elaine E. Sutherland & Lesley-Anne Barnes Macfarlane eds., 2016), pp. 51, 57).

> right: the guarantee that this principle will be applied whenever a decision is to be taken concerning a child or a group of children.[339]

165. Furthermore, such decisions must be made with an eye toward not only short-term solutions but also longer-term effects.[340] Finally, it is worth noting that Article 3 has been criticized as "paternalistic."[341] Such concerns (to whatever extent they have merit) may indicate the importance of combining Article 3's work with a focus on Article 12's requirements on taking children's opinions into account when making decisions.

166. Article 3 and Climate Change. A 2022 article by Professor Francesca Ippolito[342] offers a discussion of Article 3's relationship with climate change. Discussing the procedural elements of Article 3, she wrote:

> When the [best interest of the child] principle functions as a procedural positive obligation as to environmental and climate change issues it encompasses the State's duty to incorporate it in all relevant environmental policies, programmes and projects as well as to integrate it in all environmental legislative, administrative and judicial proceedings, in practice, in impact assessments, in the duty of cooperation and in budgeting.[343]

167. What's more, Ippolito added that this aspect of Article 3 could also apply to States' regulatory framework for "ensur[ing] that the business sector complies with international climate mitigation standards and respect[s] children's rights."[344] Interestingly, Ippolito also noted that "[t]he reporting system of the CRC and the practice of its monitoring body could be used with reference to the Paris Agreement to better specify due diligence regulatory obligations and would arguably contribute to widely amending national laws and policies."[345]

168. With respect to Article 3's role as an interpretive tool, "the best interests of the child should be employed as 'cross-cutting standards' in order to illustrate their relevance for substantive provisions of the [UNCRC] and the active measures States need to take to implement the obligation both for individual children and

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[339] *Id.*, p. 10.
[340] *Id.*
[341] Milka Sormunen, *The Best Interests of the Child in Human Rights Practice: An Analysis of Domestic, European and International Jurisprudence*, Ph.D. dissertation, University of Helsinki (12 March 2021), p. 19.
[342] Francesca Ippolito, *The Best Interests of the Child: Another String to the Environmental and Climate Protection Bow?*, 89 QUESTIONS INT'L L. 7 (2022), *supra* note 333.
[343] *Id.*, pp. 11–12 (footnotes omitted).
[344] *Id.*, p. 15.
[345] *Id.*, p. 14.

for children as a group."[346] In the context of climate change, this way of thinking means that States should "choose the interpretation that advances" children's rights, such as those that prioritize "reduced GHG emissions allocating also 'sufficient technical and financial resources to effectively mitigate the negative impacts of environmental pollution on children.'"[347]

(c) Article 6: Survival and Development

169. UNCRC Article 6 states that children have the right to survival and development. Importantly, "[t]he right to survival carries with it a more positive connotation than the right to life alone. It means the right to have positive measures taken by States in order to extend the life of the child."[348] The right to survival and development, notably, has been interpreted by the Committee to include Article 24's right to a healthy environment: "the right to survival and development can only be implemented in a holistic manner, through the enforcement of all the other provisions of the Convention, including . . . [the right to] a healthy and safe environment."[349] Along similar lines, at least one expert has written that "the right to life is inextricably linked to the right to survival, requiring measures to increase life expectancy as well as those that protect against and mitigate the consequences of climate change."[350]

170. Climate change clearly threatens these rights. As quoted previously, one set of authors has stated that "the effect of climate change on the rights of children to optimal survival and development is immeasurable and requires a concerted international effort to reverse its impending catastrophic consequences."[351]

(d) Article 12: Expressing Opinions and Being Heard

171. Article 12 enshrines the right of children to express their opinions and be listened to, not only in legislatures but also in courts. Children have been outspoken in their support for action to curb climate change, but this activism has all too often

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[346] *Id.*, pp. 17–18 (footnotes omitted) (quoting Karl Hanson & Laura Lundy, *Does Exactly What It Says on the Tin?: A Critical Analysis and Alternative Conceptualisation of the So-Called "General Principles" of the Convention on the Rights of the Child*, 25 INT'L J. CHILDREN'S RTS. 285, 299 (2017)).
[347] *Id.*, p. 18 (quoting U.N. Committee on the Rights of the Child, *Concluding observations on the fifth periodic report of Mongolia*, CRC/C/MNG/CO/5 (12 July 2017), ¶ 35(b)).
[348] Susana Sanz-Caballero, *Children's Rights in a Changing Climate: A Perspective from the United Nations Convention on the Rights of the Child*, 13 ETHICS IN SCI. & ENV'T POL. 1, 4 (2013).
[349] U.N. Committee on the Rights of the Child, *General Comment No. 7 (2005): Implementing child rights in early childhood*, CRC/C/GC/7/Rev.1 (10 September 2006), ¶ 10.
[350] Ziba Vaghri, *Article 6: The Rights to Life, Survival, and Development*, *in* MONITORING STATE COMPLIANCE WITH THE UN CONVENTION ON THE RIGHTS OF THE CHILD: AN ANALYSIS OF ATTRIBUTES 11, 12 (Ziba Vaghri et al. eds., 2022), *supra* note 316, pp. 31, 35.
[351] Jeffrey L. Goldhagen et al., *Rights, Justice, and Equity: A Global Agenda for Child Health and Wellbeing*, 4 LANCET CHILD ADOLESCENT HEALTH 80, 85 (2020), *supra* note 311, p. 85.

faced steady resistance from key decision-making entities. One particularly widespread conception of Article 12's requirements comes from what has been referred to as the "Lundy Model."[352] Under this framework, "successful implementation of Article 12 requires consideration of the implications of four separate factors: Space, Voice, Audience, and Influence."[353]

172. Crucially, "[t]okenistic inclusion of a few youth in adult-dominated forums does not qualify as proper child participation."[354] Rather, "it is important that [young people's] participation be a sustainable part of ongoing government processes and in every aspect of government functioning, with the views of children given due weight in accordance with their age and maturity."[355] Some youth parliaments represent successful implementations of that principle—particularly those with "follow-up mechanisms in place to implement the outcomes of [government officials'] consultations with children, clear channels for the decisions of child parliaments and councils to influence the proceedings of parliamentary bodies, and feedback to inform the children of the impact of their participation."[356]

173. Finally, it is worth mentioning at least a couple of the other (many) ways that children have advocated for better policies addressing climate change. Perhaps most famously, children around the world have gone on various "school strikes for climate," an idea made famous by Greta Thunberg.[357] In the legal realm, meanwhile, children have launched legal challenges in countries across the globe, "invoking the legal obligations of States to restore a stable climate system and protect their fundamental rights."[358] They have also filed claims in international courts.[359]

(e) Article 24: Health; Environment and Health

[352] *See, e.g.*, Ziba Vaghri, *Climate Change, an Unwelcome Legacy: The Need to Support Children's Rights to Participate in Global Conversations*, 28 CHILDREN, YOUTH AND ENV'TS. 104, 108 (2018) (using the term "Lundy Model").
[353] Laura Lundy, *'Voice' Is Not Enough: Conceptualising Article 12 of the United Nations Convention on the Rights of the Child*, 33 BRITISH EDUC. RSCH. J. 927, 932 (2007).
[354] Ziba Vaghri, *Climate Change, an Unwelcome Legacy: The Need to Support Children's Rights to Participate in Global Conversations*, 28 CHILDREN, YOUTH AND ENV'TS. 104, 108 (2018), *supra* note 352, p. 108.
[355] *Id.*, p. 109.
[356] *Id.*
[357] There have been a number of such strikes. *See, e.g.*, "*School Strike for Climate: Protests Staged Around the World*," BBC (24 May 2019); Damien Gayle, "*Fridays for Future School Climate Strikes Resume Across the World*," THE GUARDIAN (25 March 2022, 10:29 AM).
[358] Our Children's Trust et al., *State Obligations Regarding Children's Rights and Climate Change*, Submission to U.N. Committee on the Rights of the Child (2016 Day of General Discussion).
[359] *See, e.g.*, *Recent Case, Sacchi v. Argentina*, 135 HARV. L. REV. 1981, 1983 (2022); *Agostinho v. Portugal*, App. No. 39371/20 (currently pending before the Grand Chamber of the ECtHR).

174. Article 24(1) states that children have the right to "the enjoyment of the highest attainable standard of health."[360] Meaningfully, Article 24(2)(c) mandates in part that States "tak[e] into consideration the dangers and risks of environmental pollution" when working to ensure proper food and water access.[361] As one author noted regarding Article 24, "the right to life is necessarily linked to and dependent on the physical environment."[362] Notably, "[t]he Committee has . . . stressed that environmental interventions taken by states to address threats to children's health should also address climate change, 'as this is one of the biggest threats to children's health and exacerbates health disparities.'"[363] Because climate change poses such a large threat to children, the Committee has stated that "States should . . . put children's health concerns at the centre of their climate change adaptation and mitigation strategies."[364]

175. Climate change and children's health are inextricably linked. As one group of authors stated, "climate change [is] among the most substantial challenges to child health and paediatric [sic] health professionals."[365] On that subject, UNICEF has explained that "[t]he bulk of global burden of disease associated with climate change affects children, especially young children. Climate change can also damage or disrupt access to essential health services and clinics."[366] It is also worth specifically noting that "[a]ir pollution also directly contributes to increased respiratory diseases amongst children and therefore challenges the fulfilment of a child's right to health."[367]

176. In 2022, the Committee held that it had jurisdiction over transboundary harms, at the very least in the climate context, stating: "the collective nature of the causation of climate change does not absolve the State party of its individual responsibility that may derive from the harm that the emissions originating within its territory

[360] Convention on the Rights of the Child, 1577 UNTS 3 (20 November 1989), *supra* note 307, Art. 24(1).
[361] *Id.*, Art. 24(2)(c).
[362] Susana Sanz-Caballero, *Children's Rights in a Changing Climate: A Perspective from the United Nations Convention on the Rights of the Child*, 13 ETHICS IN SCI. & ENV'T POL. 1, 4 (2013) *supra* note 348, p. 4.
[363] John Tobin, *Article 24. The Right to Health*, *in* THE UN CONVENTION ON THE RIGHTS OF THE CHILD: A COMMENTARY 902, 948 (quoting U.N. Committee on the Rights of the Child, *General Comment No. 15 (2013) on the right of the child to the enjoyment of the highest attainable standard of health (art. 24)*, CRC/GC/15 (17 April 2013), ¶ 50).
[364] U.N. Committee on the Rights of the Child, *General Comment No. 15 (2013) on the right of the child to the enjoyment of the highest attainable standard of health (art. 24)*, CRC/GC/15 (17 April 2013), *supra* note 363, ¶ 50.
[365] Jeffrey L. Goldhagen et al., *Rights, Justice, and Equity: A Global Agenda for Child Health and Wellbeing*, 4 LANCET CHILD ADOLESCENT HEALTH 80, 85 (2020), *supra* note 311, p. 82.
[366] UNICEF, CLIMATE CRISIS, *supra* note 314, p. 111.
[367] UNICEF, CHALLENGES, *supra* note 314, p. 48.

may cause to children, whatever their location."[368] In so doing, the Committee turned away from a jurisdictional test based on "state control over the petitioners," instead relying on a "causality-based test."[369]

b. ICJ Case Law

177. International jurisprudence has recognized that the protection of the environment concerns both present and future generations. In this sense, in its *Advisory Opinion on the Legality of the Threat or Use of Nuclear Weapons*, the ICJ recognized that the environment is not a mere abstraction, but represents the living space, the quality of life, and the very health of human beings, including generations yet unborn.[370] The IACtHR has also reaffirmed that the collective dimension of the right to a healthy environment includes present and future generations.[371]

178. In his separate opinion in the *Pulp Mills Case*, Judge Antonio Cançado Trindade referred to the long-term temporal dimension of international law, particularly when referring to environmental conservation; he stated that human beings relate in space (the environment) and time (past and future), "in respect of which they have obligations."[372] For Judge Cançado Trindade, taking into account the temporal dimension of international law is also imperative in recognizing indigenous cosmovisions that see a performance of their duty to transmit their culture to future generations in their conservation and preservation of the land,[373] echoing the jurisprudence of the IACtHR in *Myagna (Sumo) Awas Tingni V. Nicaragua*.[374]

179. The Committee on Economic Social and Cultural Rights has also recognized that the notion of sustainability for the enjoyment of economic, social, and cultural

[368] U.N. Committee on the Rights of the Child, *Decision adopted by the Committee under the Optional protocol to the Convention on the Rights of the Child on a communications procedure, concerning communication No. 104/2019* (S*acchi et al. v. Argentina*), CRC/C/88/D/104/2019 (22 September 2021), ¶ 10.10. The case in which this decision was rendered was named *Sacchi v. Argentina*. *Id.*
[369] *Recent Case, Sacchi v. Argentina*, 135 HARV. L. REV. 1981 (2022), *supra* note 359, p. 1983.
[370] *Legality of the Use by a State of Nuclear Weapons in Armed Conflict*, Advisory Opinion, ICJ Reports 1996 (8 July 1996), ¶ 39.
[371] *State Obligations in Relation to the Environment in the Context of the Protection and Guarantee of the Rights to Life and Personal Integrity: Interpretation and Scope of Articles 4(1) and 5(1) in Relation to Articles 1(1) and 2 of the American Convention on Human Rights*, Advisory Opinion OC-23/17 (Requested by the Republic of Colombia), IACthR (15 November 2017).
[372] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Separate Opinion of Judge Cançado Trindade, ICJ Reports 2010 (20 April 2010), ¶ 114.
[373] *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, Separate Opinion of Judge Cançado Trindade, ICJ Reports 2010 (20 April 2010).
[374] *Case of the Mayagna (Sumo) Awas Tingni Community v. Nicaragua*, Judgment, 79 IACtHR (Ser. C) (31 August 2001).

rights implies that such rights are accessible to present and future generations.[375] This implies adopting urgent measures to mitigate and adapt to climate change.[376]

180. Intergenerational equity has also been invoked by the U.N. Human Rights Committee in two cases concerning the protection of human rights in the face of the climate crisis. In *Teitiota v. New Zealand*, the Committee noted that environmental degradation, climate change, and unsustainable development are among the most pressing and serious threats to the ability of present and future generations to enjoy the right to life.[377] Additionally, in *Torres Straits Islanders v. Australia*, the Committee recognized that the principle of intergenerational equity imposes a duty on present generations to act as responsible stewards of the planet and to ensure the right of future generations to meet their developmental and environmental needs.[378] In this regard, the Committee highlighted that Australia's failure to take adequate and timely adaptation measures negatively impacted the intergenerational dimension of indigenous peoples' right to culture.[379]

c. Climate Litigation

181. Domestic rulings have also recognized intergenerational equity as a cross-cutting principle in climate action, and its invocation has been a persuasive argument for national courts to raise climate ambition of States.[380] In the *Oposa v. Factoran* (1992) case, the plaintiffs were minors who were acting on their own behalf, but also on behalf of unborn generations. In this regard, the Philippine Supreme Court held that the plaintiffs had standing to bring such a claim based on the concept of intergenerational responsibility, according to which each generation must preserve the rhythm and harmony of nature for the full enjoyment of a healthy and balanced ecology for future generations. Consequently, the Court ruled that the assertion by minors of their right to a healthy environment constituted, at the

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[375] U.N. Committee on Economic, Social, and Cultural Rights, *General Comment No. 15, The right to water (articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights)* (2002), ¶ 28.
[376] OHCHR, FREQUENTLY ASKED QUESTIONS ON HUMAN RIGHTS AND CLIMATE CHANGE: FACT SHEET NO. 38 (2021), p. 57.
[377] U.N. Human Rights Committee, *Ioane Teitiota v. New Zealand*, Admissibility and Merits Views, No. 2728/2016, CCPR/C/127/D/2728/2016 (23 September 2020), ¶ 9.4.
[378] U.N. Human Rights Committee, *Daniel Billy et al. v. Australia*, Admissibility and Merits Views, No. 3624/2019, CCPR/C/135/D/3624/2019 (22 September 2022), ¶ 5.8.
[379] Ibid, ¶ 8.14.
[380] *See, e.g*, *Neubauer et al. v. Germany*, Order on the Constitutional Complaint, Bundesverfassungsgericht [BVerfG] (German Federal Constitutional Court), Case No. BvR 2656/18/1, BvR 78/20/1, BvR 96/20/1, BvR 288/20 (24 March 2021); *Lozano Barragán and others v. Presidency of the Republic of Colombia and others*, Sala Cas. Civil CSJ Colombia, No. STC4360-2018 (5 April 2018); and Second District Judge in Administrative Matters Specialized in Economic Competition, Broadcasting and Telecommunications Mexico, Amparo Indirecto 104/2020 (17 November 2020).

same time, the fulfillment of their obligation to ensure the protection of said right for future generations.[381]

182. In the *Future generations v. Ministry of the Environment* (2018) case, the Colombian Supreme Court of Justice ordered the government to take concrete measures against deforestation in the Amazon, recognizing that the effects of deforestation would imply an increase in GHG emissions in Colombia, and therefore in its temperature, thus violating the human rights of future generations. For the Colombian Supreme Court, future generations are subjectsto constitutional protection. The Court interpreted that unborn subjects "deserve to enjoy the same environmental conditions enjoyed by us."[382] In this regard, the Supreme Court considered that the environmental rights of future generations have anthropocentric (the ethical duty of solidarity of the species) and ecocentric (the intrinsic value of nature) justifications.[383] Both foundations lead to the establishment of an obligatory relationship between present and future generations, which translates into a limitation of the freedom of present generations, as well as the imposition of new burdens of environmental care.[384]

183. In the specific case, the Supreme Court found that deforestation in the Amazon between 2015 and 2016 increased by 44%, generating a serious and imminent damage to present and future generations, insofar as it "uncontrollably unleashed the emission of carbon dioxide, producing the greenhouse effect."[385] The Supreme Court analyzed this situation in light of different environmental principles, including intergenerational equity. Thus, it determined an "obvious transgression" of intergenerational equity, since "the temperature in the year 2041 will be 1.6C and in 2071 up to 2.14C, being future generations . . . those who will be directly affected, unless the present ones reduce the rate of deforestation to zero."[386] For the above reasons, the Supreme Court ordered government authorities to establish a program to reduce the rate of deforestation in the Amazon to address climate change.

184. In the case of *Raja Zahoor Ahmed v. Capital Development Authority* (2015), the Supreme Court of Pakistan ruled that several conversions of residential properties to commercial ones were unlawful, and noted the relevance for climate awareness in urban planning to guarantee the rights of future generations. Specifically, the

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[381] *Oposa et al. v. Fulgencio S. Factoran, Jr. et al.*, Supreme Court of the Philippines, G.R. No. 101083 (30 July 1993).
[382] *Andrea Lozano Barragán, Victoria Alexandra Arenas Sánchez, José Daniel Rodríguez Peña y otros Vs. Presidencia de la República, Ministerios de Ambiente y Desarrollo Sostenible y de Agricultura y Desarrollo Rural y otros*, Sala Cas. Civil CSJ Colombia, No. STC4360-2018 (5 April 2018), ¶¶ 11.1–11.3.
[383] Ibid., ¶ 5.2.
[384] Ibidem.
[385] Ibid, ¶ 11.
[386] Ibid, ¶ 11.

Court noted that "climate-resilient development in cities of all sizes is crucial for improving the well-being of people and increasing the life opportunities of future generations."[387]

185. Moreover, intergenerational equity has also been a relevant argument made against regressive environmental policies.[388] In this sense, the Pennsylvania Supreme Court ruled in *Robinson Township v. Commonwealth* that Pennsylvania's Act 13 of 2012, which amended the State's Oil and Gas Act, violated several human rights of the plaintiffs. Among other relevant environmental regressions, the challenged Act limited the authority of local governments to regulate oil and gas operations. In its ruling, the Pennsylvania Supreme Court indicated that "the Commonwealth's obligations as trustee to conserve and maintain the public natural resources for the benefit of the people, including generations yet to come, create a right in the people to seek to enforce the obligations."[389] In this sense, the Court found that "the exploitation of the Marcellus Shale Formation will produce a detrimental effect on the environment, on the people, their children, and future generations, and potentially on the public purse, perhaps rivaling the environmental effects of coal extraction."[390] For this reason, the Court ruled that several articles of legislative reform violated the environmental rights clause of the Constitution of Pennsylvania.[391]

186. In Germany, several young people argued before the Federal Constitutional Court that the 55% emission reduction target for 2030 (postulated in the federal climate law) was insufficient and in violation of their human rights, as well as the central objective of the Paris Agreement. In *Neubauer et al. v. Germany* (2021), the Federal Court ruled that the State must set its emission reductions considering the long-term impact that such reductions may have on the rights of future generations.[392] Thus, an unambitious reduction would imply, in the future, a disproportionate restriction of the rights of the German population compared to the restrictions

[387] *Raja Zahoor Ahmed v. Capital Development Authority*, Order, Supreme Court of Pakistan, [1996] PLD 569 (20 May 2022), ¶ 9.
[388] *See, e.g.*, *In the Matter of the Application of Hawai'i Electric Light Company, Inc. for Approval of a Power Purchase Agreement for Renewable Dispatchable Firm Energy and Capacity*, Opinion of the Court by Eddins, J., Docket No. 2017—0122, SCOT-22-0000418 (13 March 2023).
[389] *Robinson Township v. Commonwealth of Pennsylvania*, Decision, Pennsylvania Supreme Court, [2013] 83 A.3d 901 (19 December 2013), ¶ 12.
[390] Ibidem.
[391] In 1971, Pennsylvania had introduced a constitutional amendment recognizing the environmental rights of current and future generations: "the people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people". Pennsylvania Constitution (1971), Art. I, § 27.
[392] *Neubauer et al v. Germany*, Bundesverfassungsgericht [BVerfG] (German Federal Constitutional Court), 1 BvR 3084/20 (2021), ¶ 92.

imposed on the rights of present generations.[393] In its reasoning, the Federal Court understood that the younger generation of people who sued the German government would be those who would bear the bulk of the costs arising from climate change. Thus, the court pointed out that the costs will not be paid by the polluters of the past, but by future generations of taxpayers as the "damage caused by climate damage is intergenerational damage."[394] In this regard, the court considered that, in view of the worsening climate crisis and the risks it entails for human dignity and the natural foundations of life, it is to be expected that a climate protection law, in responsibility towards future generations, should at least take the necessary precautions so that—as far as possible and proportionate—no further GHGs are released.[395] For these reasons, the Federal Court found that the climate ambition of the German legislation violated the human rights of the plaintiffs, as it did not reflect the highest possible ambition in the reduction of GHG emissions.[396]

[393] Ibid., ¶¶ 191–199.
[394] Ibid., ¶ 40.
[395] Ibid., ¶ 110.
[396] Ibid., ¶ 130.

ANEXO 2

7-2023

Global Climate Litigation Report: 2023 Status Review

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Global Climate Litigation Report

2023 Status Review

UN environment programme

Columbia Law School | Columbia Climate School
Sabin Center for Climate Change Law

Global Climate Litigation Report

2023 Status Review

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List of abbreviations and acronyms

BNDES	Brazilian National Development Bank
CJEU	Court of Justice of the European Union
CO_2	Carbon dioxide
CSPP	Corporate Sector Purchase Programme
ECHR	European Convention on Human Rights
ECtHR	European Court of Human Rights
EIA	Environmental impact assessment
EPA	Environmental Protection Agency
GHG(s)	Greenhouse gas(es)
HRC	United Nations Human Rights Council
IACHR	Inter-American Commission of Human Rights
IACtHR	Inter-American Court of Human Rights
ICC	International Criminal Court
ICSID	International Centre for Settlement of Investment Disputes
IPCC	Intergovernmental Panel on Climate Change
ISDS	Investor-State dispute settlements
ITLOS	International Tribunal for the Law of the Sea
NDC	Nationally determined contribution
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Contents

Foreword

The climate crisis is getting worse, not better. Every year, the impacts of climate change are getting more intense. Every year, hundreds of millions of people endure increasingly regular extreme weather events, taking away livelihoods and lives. Every year, our economies – and in some cases, entire countries – begin to see the reality of an uncertain future. As the United Nations Secretary-General summarized to delegates gathered in Egypt at the twenty-seventh Conference of the Parties to the United Nations Framework Convention on Climate Change in November 2022, "We are in the fight of our lives, and we are losing."

Climate litigation represents a frontier solution to change the dynamics of this fight. As this report shows, people are increasingly turning to the courts to combat the climate crisis. Governments and private sector entities are being increasingly challenged and held to account. Children and youth, women's groups, local communities and Indigenous Peoples, among others, are also taking a more prominent role in bringing these cases and driving climate change governance reform in more and more countries around the world.

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The legal grounds for these cases are also widening. Both the United Nations Human Rights Council and the United Nations General Assembly have now recognized the right to a clean, healthy and sustainable environment. We are seeing new claims centred around the violation of legislation related to net-zero targets, environmental impact assessments, advertising standards, and obligations under the Paris Agreement. Climate litigation has set precedents for climate action all over the globe, going beyond the jurisdictions in which they were brought and empowering and driving similar action in other countries.

This report demonstrates the importance of an environmental rule of law in combating the triple planetary crises of climate change, biodiversity loss and pollution. Access to justice enables the protection of environmental law and human rights and promotes accountability in public institutions. It is not enough that we recognize human rights, we must make every effort to protect and uphold them and enable individuals to seek redress where they are violated.

I would like to acknowledge the outstanding support of the Sabin Center for Climate Change Law at Columbia University. Our collaboration in producing the *Global Climate Litigation Report: 2023 Status Review* would not have been possible without their dedication and commitment.

Patricia Kameri-Mbote
Director of the Law Division
United Nations Environment Programme

Executive summary

Climate ambition around the world remains inadequate to meet the challenge of our climate crisis. Despite improvement in countries' mitigation and adaptation targets, and despite numerous corporate pledges to achieve net-zero emissions in the future, the international community is still a long way from achieving the goals and objectives of the Paris Agreement. In response, individuals, children and youth, women and human rights groups, communities, Indigenous groups, non-governmental organizations (NGOs), business entities, and national and subnational governments have turned to courts, tribunals, quasi-judicial bodies or other adjudicatory bodies, including special procedures of the United Nations and arbitration tribunals, seeking relief through:

- **(i)** The enforcement of existing climate laws
- **(ii)** Integration of climate action into existing environmental, energy and natural resources laws
- **(iii)** Orders to legislators, policymakers and business enterprises to be more ambitious and thorough in their approaches to climate change
- **(iv)** Establishment of clear definitions of human rights and obligations affected by climate change
- **(v)** Compensation for climate harms

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As these cases become more frequent and numerous overall, the body of legal precedent grows, forming an increasingly well-defined field of law.

This *Global Climate Litigation Report: 2023 Status Review*, which updates previous United Nations Environment Programme reports published in 2017 and 2020, provides an overview of the current state of climate change litigation and an update of global climate change litigation trends. It provides judges, lawyers, advocates, policymakers, researchers, environmental defenders, climate activists, human rights activists (including women's rights activists), NGOs, businesses and the international community with an essential resource to understand the current state of global climate litigation, including descriptions of the key issues that courts have faced in the course of climate change cases.

While the legal arguments and the adjudicative forums in which they are brought vary greatly, climate change cases have typically addressed similar key legal issues. Like the 2017 and 2020 Litigation Reports, this report summarizes those issues, which include challenges to whether the court has the power to resolve the dispute, identifying the source of an enforceable climate-related right or obligation, crafting a remedy that will lessen the plaintiffs' injuries, and, importantly, marshalling the science of climate attribution. Over the course of reporting on these issues, it is clear that parties are putting forward innovative arguments on connections between a specific greenhouse gas emitter's actions and global climate change, and how foreseeable climate-driven impacts can be linked to specific harms suffered by plaintiffs.

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Part 1 describes the importance of climate change litigation through an overview of the environmental, diplomatic and political circumstances that make climate change litigation efforts especially important.

Part 2 provides an overview of global climate litigation through an analysis of the overall number of gathered cases and their geographic distribution. As described in more detail elsewhere in this report, the cases analysed here were collected by the Sabin Center for Climate Change Law in its Climate Change Litigation databases.

Part 3 provides a survey of the state of climate change litigation and a discussion of evident and emerging trends.

Part 4 describes the types of climate cases that suggest where global climate change litigation may be heading in the coming years.

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As at 31 December 2022, the Sabin Center's Climate Change Litigation databases included 2,180 cases filed in 65 jurisdictions and international or regional courts, tribunals, quasi-judicial bodies, or other adjudicatory bodies, including special procedures of the United Nations and arbitration tribunals. This number includes 1,522 cases in the United States of America and 658 cases in all other jurisdictions combined.

In summary, climate change litigation is increasing and broadening in geographical reach, while the range of legal theories is expanding. It has become clear – and is now recognized by the Intergovernmental Panel on Climate Change – that inclusive approaches to climate litigation that also address the human rights of the most vulnerable groups in society can contribute in meaningful ways to compel governments and corporate actors to pursue more ambitious climate change mitigation and adaptation goals.

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Introduction

Introduction

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The United Nations Environment Programme (UNEP) published its first survey of global climate change litigation in 2017 (UNEP 2017)[1] and the second instalment in 2020 (UNEP 2020).[2] These reports identified key developments, profiled significant cases, described then-current and emerging trends, and outlined critical legal issues in climate change cases. This 2023 Litigation Report represents the third instalment of the global survey on climate litigation. It updates the status of cases that were still pending when they were featured in the previous reports, follows up on key trends that have continued in intervening years, and outlines legal changes, new trends and emerging issues in climate litigation.

The report analyses pending cases, decisions and trends in the 2020–2022 period, as well as cases added to the Climate Change Litigation databasebs maintained by the Sabin Center for Climate Change Law (Sabin Center), as part of the Sabin Center's launch of the Peer Review Network of Global Climate Litigation ("the Network"). The publication also briefly highlights women's role in climate change litigation. This places women not only as victims disproportionately suffering the impacts of climate change, but also shows their contributions towards environmental justice for everyone's benefit. These inextricable linkages are important to the achievement of the Sustainable Development Goals by 2030, which call for gender equality and human rights as key objectives. Except where otherwise noted, this report contains information correct as at 31 December 2022.

1 Throughout this report, we refer to this previous UNEP report on climate litigation as the "2017 Litigation Report".
2 Throughout this report, we refer to this previous UNEP report on climate litigation as the "2020 Litigation Report".

Box 1: Defining "climate change litigation"

This report follows the definition of "climate change litigation" used by the Sabin Center in the development and maintenance of its Climate Change Litigation databases. Under this definition, climate change litigation includes cases that raise material issues of law or fact relating to climate change mitigation, adaptation or the science of climate change (Sabin Center for Climate Change Law 2022a).[3] Such cases are brought before a range of administrative, judicial and other adjudicatory bodies. These cases are typically identified by the Sabin Center with keywords like "climate change", "global warming", "global change", "greenhouse gas", "GHGs" and "sea level rise". Cases that raise issues of law or fact related to climate change but do not use those or other specific terms are also included.

This report excludes cases where the discussion of climate change is incidental, or where a non-climate legal theory would guide the substantive outcome of the case. Thus, when climate change keywords are only used as a passing reference to the fact of climate change and those issues are not related to the laws, policies or actions actually at issue, the case is excluded.

Similarly, this report excludes cases that seek to accomplish goals arguably related to climate change adaptation or mitigation, but their resolution does not depend on the climate change dimensions of those goals. For example, lawsuits seeking to use human health regulations to limit air pollution from coal-fired power plants may incidentally cause a court to compel that power plant to emit a lower level of greenhouse gases (GHGs). Such cases are not considered "climate change litigation" for the purposes of this study (Peel and Lin 2019).[4]

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3 This definition guides the collection of cases included in the Climate Change Litigation databases, which are developed and maintained by the Sabin Center for Climate Change Law at Columbia Law School. See also Part 2.II.
4 Peel and Lin (2019) note that in the Global South, in particular, cases are less likely to fit into the definition of climate change litigation used here. On pages 690 and 691, they argue that analyses of climate change litigation should include matters in which climate change is a peripheral issue because those cases still "make an important contribution to climate governance". On the other hand, on page 695, they similarly exclude matters where climate change is mentioned only incidentally.

> "Notably, both the 2020 and 2023 Litigation Reports conclude that litigation is central to efforts to compel governments and corporate actors to undertake more ambitious climate change mitigation and adaptation goals"

This report proceeds in five parts:

Part 1 sets the stage by describing the growing urgency of the climate crisis and the role that climate change litigation plays in the domains of climate law and policy.

Part 2 surveys the current status of global climate change litigation, drawn from the cases included in the Sabin Center's Climate Change Litigation databases. This section provides a broad overview of the data of global climate litigation, including a comprehensive regional analysis.

Part 3 assesses current trends in climate litigation. Those trends reflect continued and increasing numbers of cases focused on one or more of the following:

- **(i)** The use of "climate rights" in climate litigation
- **(ii)** Domestic enforcement
- **(iii)** Keeping fossil fuels and carbon sinks in the ground
- **(iv)** Corporate liability and responsibility
- **(v)** Climate disclosures and greenwashing
- **(vi)** Failure to adapt and the impacts of adaptation

Part 4 reflects the predictions for emerging trends, including a few updates from the 2020 Litigation Report and others that are freshly observed. Notably, both the 2020 and 2023 Litigation Reports conclude that litigation is central to efforts to compel governments and corporate actors to undertake more ambitious climate change mitigation and adaptation goals, and litigants around the world continue to expand the range of theories under which defendants are obligated to take climate-related action.

Lastly, summaries of significant cases appear throughout this report, providing context and examples of those issues and the trends they comprise.

Part 1: The importance of climate change litigation

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Part 1: The importance of climate change litigation

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While GHG emissions temporarily dropped in the first half of 2020 due to the COVID-19 pandemic, emissions rebounded by the end of the year (Intergovernmental Panel on Climate Change [IPCC] 2022). In 2021, global energy-related carbon dioxide (CO_2) emissions rose by 6 per cent above 2020 levels to 36.3 billion tons, their highest level ever (International Energy Agency 2022). Overall, CO_2 emissions rebounded by 4.8 per cent in 2021, consuming 8.7 per cent of the remaining carbon budget (IPCC 2018)[5] for limiting anthropogenic warming to 1.5°C (Liu *et al.* 2022).

At 1.1°C, global warming is already causing widespread disruption worldwide, including droughts, extreme heat, record floods and storms, food insecurity, wildfires, the harming of species and ecosystems as well as the enabling of vector-borne disease transmission (IPCC 2022). Scientists have warned that every tenth of a degree of additional warming will escalate threats to people, species and ecosystems (IPCC 2022). Furthermore, the effects of climate change are disproportionately felt across the globe and by populations in vulnerable situations, causing gender and income inequalities and development challenges, especially in the Global South and in small island developing States.[6] IPCC has stated that climate change unequivocally endangers the well-being of people and ecosystems throughout the globe. Delayed climate action poses irreversible risks, with a narrow window of opportunity to realize a sustainable and liveable future.

> **"Climate change litigation provides civil society, individuals and others with one possible avenue to address inadequate responses by governments and the private sector to the climate crisis."**

In the lead-up to the twenty-seventh Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), the UNFCCC secretariat analysed the nationally determined contributions (NDCs) of 166 countries, covering 94.9 per cent of the total global emissions in 2019 (UNFCCC 2022a). To keep the long-term temperature goal set out in article 2 of the Paris Agreement and limit global temperature rise to 1.5°C, countries need to significantly cut global emissions in half by the end of this decade. However, the UNFCCC secretariat estimated that, based on the latest NDCs, countries would likely use up 89 per cent of the remaining carbon budget in 2020–2030 (UNFCCC 2022a). In its 2022 Emissions Gap Report, UNEP calculated that recent pledges "make a negligible difference to predicted 2030 emissions" and that current policies point to a 2.8°C warming by the end of the century. While that trajectory is a significant improvement from the prior estimate of a 4°C warming scenario, it remains far beyond the goals set forth under the Paris Agreement (UNEP 2022). At the same time, in its 2021 Production Gap Report, UNEP concluded that governments plan to produce more than double the amount of fossil fuels in 2030 than would be consistent with limiting global warming to 1.5°C. The Glasgow Climate Pact (Decision 1/CMA.3) has called on countries to "revisit and strengthen" their 2030 targets by the end of 2022 to align them with the Paris Agreement's temperature goals (UNFCCC 2022b). It also asks all countries that have not yet done so to submit long-term strategies to 2050, aiming for a just transition to net-zero emissions around mid-century.

Climate change litigation provides civil society, individuals and others with one possible avenue to address inadequate responses by governments and the private sector to the climate crisis. In climate cases, plaintiffs, petitioners, applicants, complainants or communicants (referred throughout as plaintiffs), through a variety of legal strategies in a wide range of national and international jurisdictions, often seek to compel more ambitious mitigation and adaptation goals from the public and private sectors. However, plaintiffs also sometimes seek to challenge climate regulations and reduce climate ambition. In its Sixth Assessment Report, IPCC recognized, for the first time (with medium confidence), that climate litigation has influenced the outcome and ambition of climate governance (Dubash *et al.* 2022). IPCC also identified climate litigation as an important avenue for actors to influence climate policy outside of the formal UNFCCC processes (Dubash *et al.* 2022). In addition, successful cases brought by plaintiffs have motivated the filing of similar claims in other jurisdictions. For example, the decision in Urgenda Foundation v. State of the Netherlands, the first time in which a court found a government to be responsible for mitigating GHG emissions, has brought a wave of ambition cases in other countries, most of which specifically mention the decision

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5 Total carbon budget is defined by the IPCC as: "Estimated cumulative net global anthropogenic CO_2 emissions from a given start date to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions."

6 The phrase "Global South" refers broadly to the regions of Latin America and the Caribbean, Asia, Africa and Oceania, and denotes regions that are mostly low-income and often politically or culturally marginalized. However, it must be noted that the Global South is not a homogeneous group of countries, and that legal development and legal capacity vary by country.

despite it not being an authoritative source of law beyond the Netherlands (Supreme Court of the Netherlands 2019).[7] With increased scientific research on climate science and attribution, and with novel legal theories being explored under international and domestic climate law, climate litigation continues to expand in scope.

Additionally, it is worth noting the energy crisis that resulted from the aggression by the Russian Federation against Ukraine. In a few instances, governments' plans to rearrange their energy supplies away from fossil fuels were adapted to these circumstances, further jeopardizing the achievement of the goals of the Paris Agreement (Climate Action Tracker 2022). With gas production and infrastructure expansion planned to respond to the energy crisis worldwide, climate litigation may arise to avoid further delays in the energy transition.

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7 *Urgenda Foundation v. State of the Netherlands*, Supreme Court of the Netherlands, Case No. 19/00135, 20 December 2019 (Netherlands). For the importance of the case, see the 2020 Litigation Report, pages 13 and 15.

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Part 2: Overview of global climate litigation

Part 2: Overview of global climate litigation

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Part 2 surveys the current status of global climate change litigation, drawn from the cases included in the Sabin Center's Climate Change Litigation databases. Unless otherwise noted, the cases featured in this 2023 Litigation Report were updated until December 2022 and were pending determination by the forums in which they were brought.

I. Methodology

This report adopts the narrow approach to defining climate change litigation used by the Sabin Center in identifying cases for inclusion in its Climate Change Litigation databases (see Box 1: Defining climate change litigation) (Sabin Center 2022a). Under this definition, climate change litigation includes cases before judicial and quasi-judicial bodies that involve material issues of climate change science, policy or law. Thus, cases must satisfy two key criteria for inclusion. First, cases must generally be brought before judicial bodies, though in some exemplary instances matters brought before administrative or investigatory bodies are also included. Second, climate change law, policy or science must be a material issue of law or fact in the case. Cases that make only a passing reference to climate change but do not address climate-relevant laws, policies or actions in a meaningful way are omitted. In general, cases that may directly impact climate change mitigation and adaptation strategies, but do not explicitly raise climate issues, are also not included. The databases and this report refer to international or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies in addition to specific jurisdictions. These include complaints submitted to special procedures of the United Nations Human Rights Council (HRC), the United Nations Secretary-General, UNFCCC and other United Nations bodies (including the United Nations Human Rights Committee and the United Nations Committee on the Rights of the Child), arbitration tribunals (International Centre for Settlement of Investment Disputes [ICSID], Stockholm Chamber of Commerce and the Permanent Court of Arbitration), and complaints before the Organisation for Economic Co-operation and Development (OECD).

As part of its continual effort to update and maintain the Global Climate Change Litigation Database, the Sabin Center launched the Network in December 2021. As at 31 December 2022, the Network includes 113 practitioners and scholars who act as "national rapporteurs" for 107 jurisdictions or international or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies (Sabin Center 2022b). In addition, several researchers and academic institutions have established national or regional climate litigation databases, including in Latin America and the Caribbean (Tigre, Ortúzar and Dávalos 2022), Brazil (JusClima 2030 2022; JUMA 2022), Australia (University of Melbourne 2022), and Southeast Asia (Litigasia 2022). While the definitions of relevant litigation and the methodologies for case collection differ among the databases, the Sabin Center has partnered with some of them to share information about cases using the Sabin Center's definition where applicable.[8]

Unless otherwise noted, cases were updated until 31 December 2022. This report deals with a fast-moving field and the subject matter may become quickly outdated. Readers are advised to check the main sources cited for updates and new materials. However, UNEP considers the fundamentals of climate change litigation as discussed in this report to be more durable and likely to remain relevant in the immediate future.

This report adopts a qualitative approach to surveying global climate litigation, informed by quantitative information where relevant. In identifying trends and cases as significant, the report considers the potential impact of the litigation within a jurisdiction and beyond the case itself, the novelty and complexity of the legal theories and issues involved, and the likelihood of the litigation influencing future cases and climate policy.

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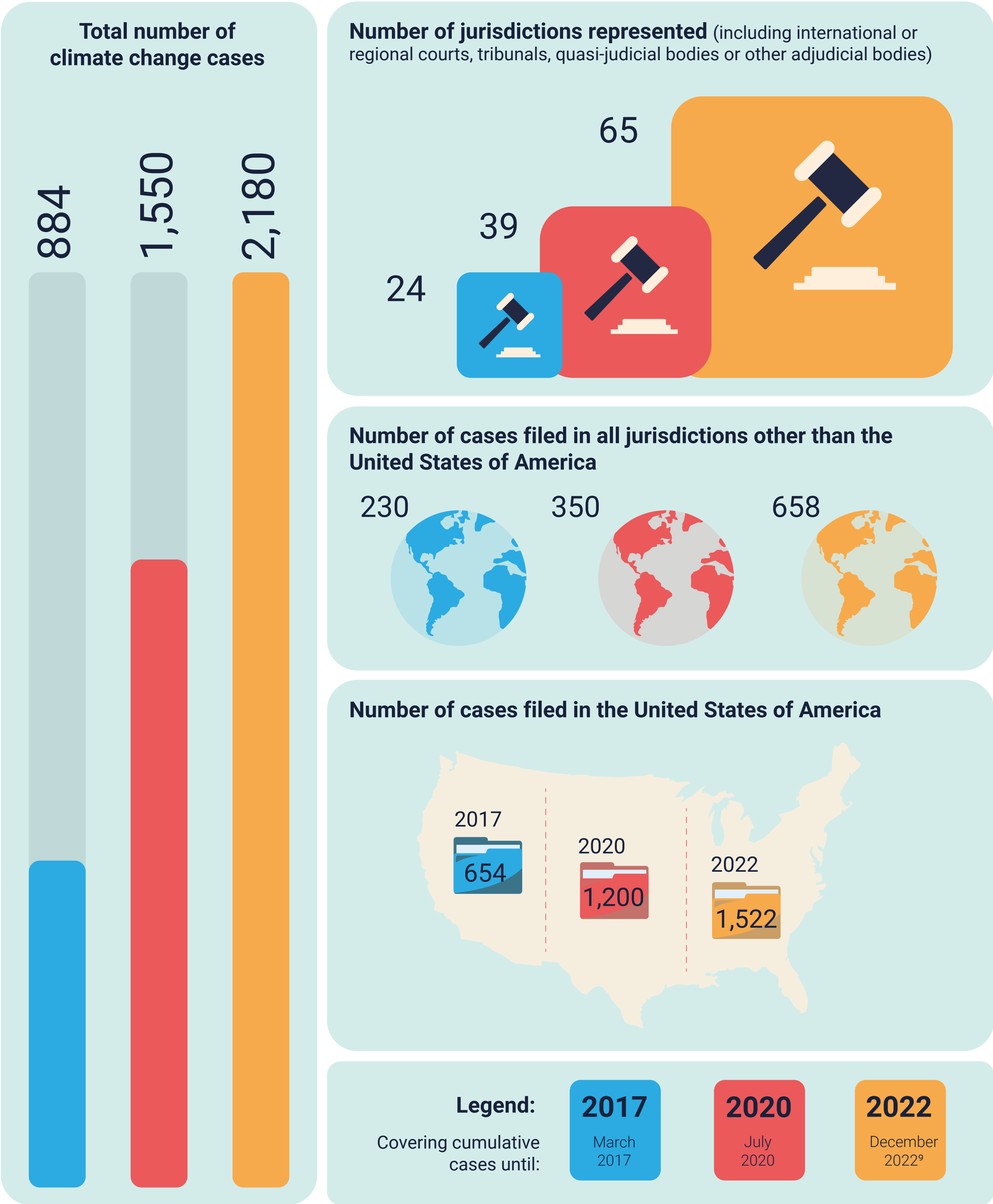
8 The Sabin Center has partnered with the Interamerican Association for Environmental Defense for rights-based cases in Latin America and the Caribbean, as well as with national databases in Brazil and Australia.

Figure 1. **Growth of climate litigation** as represented in UNEP's 2017, 2020 and 2023 Litigation Reports



9 As a result of the Network, the number of cases in the Sabin Center's databases have increased substantially. These include cases filed before 2020 as well as new cases filed in 2021 and 2022. All cases added to the database as a result of the Network's contributions are included in this report, including those filed before the publication of the 2020 Litigation Report.

II. Survey of climate change litigation

Climate litigation is a growing field, and both the number of cases filed and the number of jurisdictions within which they have been brought have increased in recent years. The 2020 Litigation Report identified 1,550 cases brought in 39 jurisdictions, including international or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies, such as special procedures of HRC, arbitration tribunals, international adjudicatory bodies and the European Union. These include 1,200 cases in the United States of America and 350 cases in all other jurisdictions combined. As at 31 December 2022, the cumulative number of cases tracked in the Sabin Center's databases has increased, with 2,180 climate change cases filed in 65 jurisdictions.[10] This number includes 1,522 cases in the United States of America and 658 cases in all other jurisdictions combined. Figure 1 compares the numbers of cases and jurisdictions covered in the three instalments of the litigation reports.

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10 The jurisdictions in which climate change cases were identified in the database for the first time since the publication of the 2020 Litigation Report are: China, Czech Republic, Guyana, Estonia, Finland, Papua New Guinea, Republic of Korea, Russian Federation, Türkiye, the East African Court of Justice and the International Tribunal for the Law of the Seas.

As Figure 1 shows, the overall number of climate litigation cases has grown since 2017, and the cumulative number of cases is now 2.5 times higher than five years ago. Figure 2 provides a visual representation of how climate litigation cases worldwide are steadily increasing. The increase in the number of cases since the 2020 report relates not only to cases filed in the period covered in this report (July 2020 to December 2022) but also, as detailed in Part 4, older cases recently added to the databases as part of the creation of the Network.

Still, there are countries in which there is still limited information about the extent of climate litigation. Therefore, it is likely that more cases in jurisdictions not yet represented will be brought to light in the near future. The research conducted by the Sabin Center on the databases is an ongoing process. While this research has significantly expanded in geographical scope, its coverage of jurisdictions is not yet universal.[11]

Figure 2.

Growth of climate change litigation as represented in the 2017, 2020 and 2023 Litigation Reports

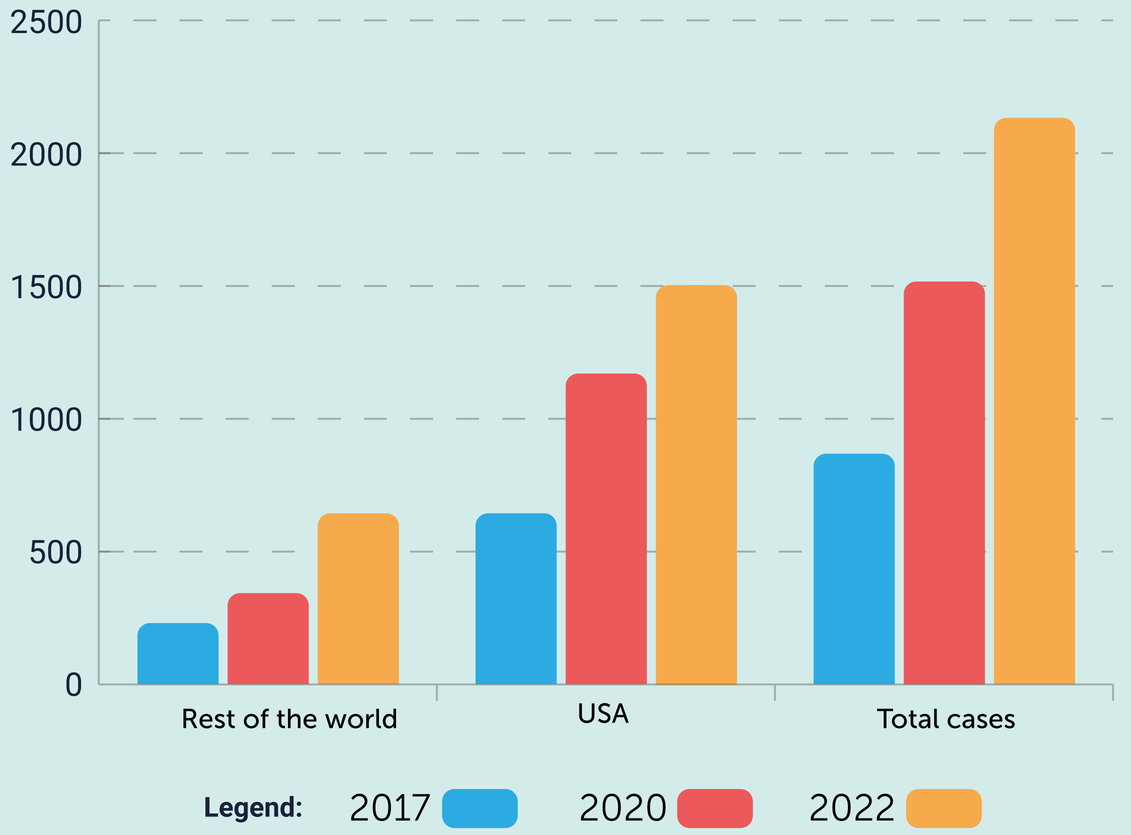


Figure 3.

Number of jurisdictions covered in the databases as represented in the 2017, 2020 and 2023 Litigation Reports

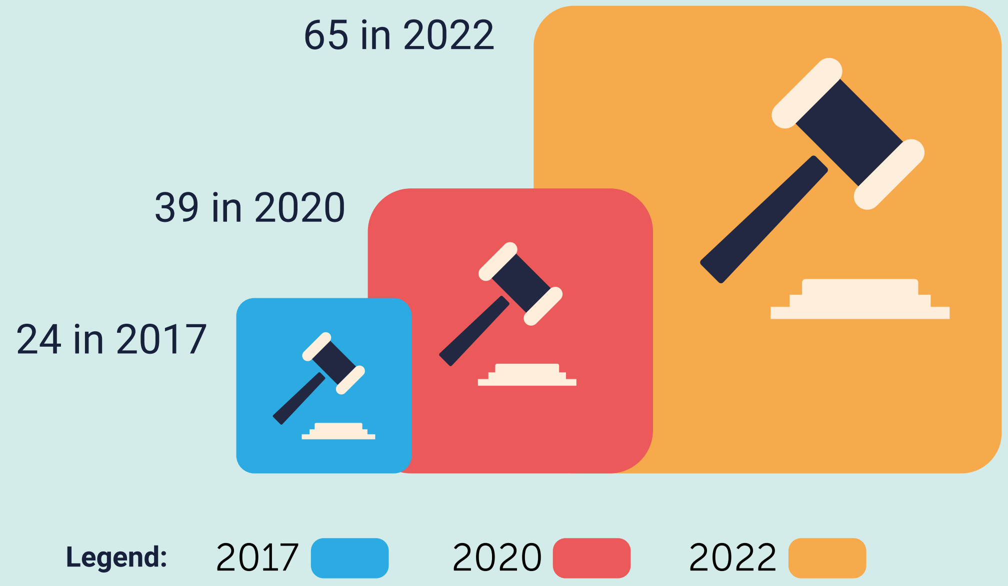


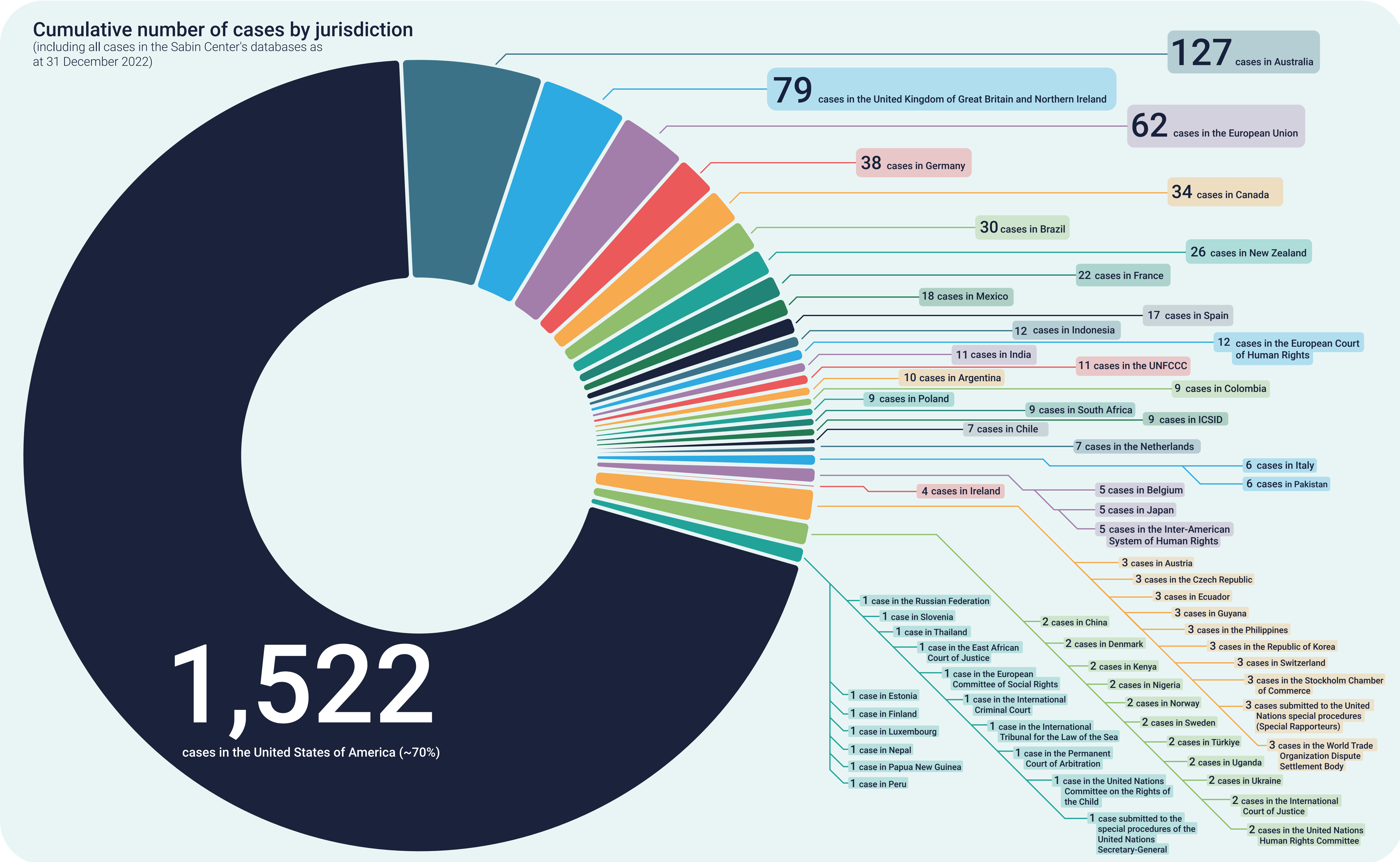
Figure 3 shows the increase in the geographic representation covered in the three instalments of the report. The 2017 Litigation Report included cases from 24 jurisdictions and the 2020 report from 39 jurisdictions. This 2023 report includes cases from 65 jurisdictions. These include international or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies. This proliferation shows that climate litigation is expanding its regional reach, with cases in the Global South particularly gaining new visibility.

III. Regional representation of climate change litigation

As at 31 December 2022, the Sabin Center's Climate Change Litigation databases include 1,522 cases filed in the United States of America and 658 filed in all other jurisdictions combined, including international or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies, such as special procedures of HRC, arbitration tribunals and the European Union. Figure 4 (overleaf) shows the number of cases per jurisdiction.

11 For the countries where the Sabin Center's Network does not yet have rapporteurs, the Sabin Center relies on other sources of data, including cases mentioned in the media and in scholarship, among others.

Figure 4.



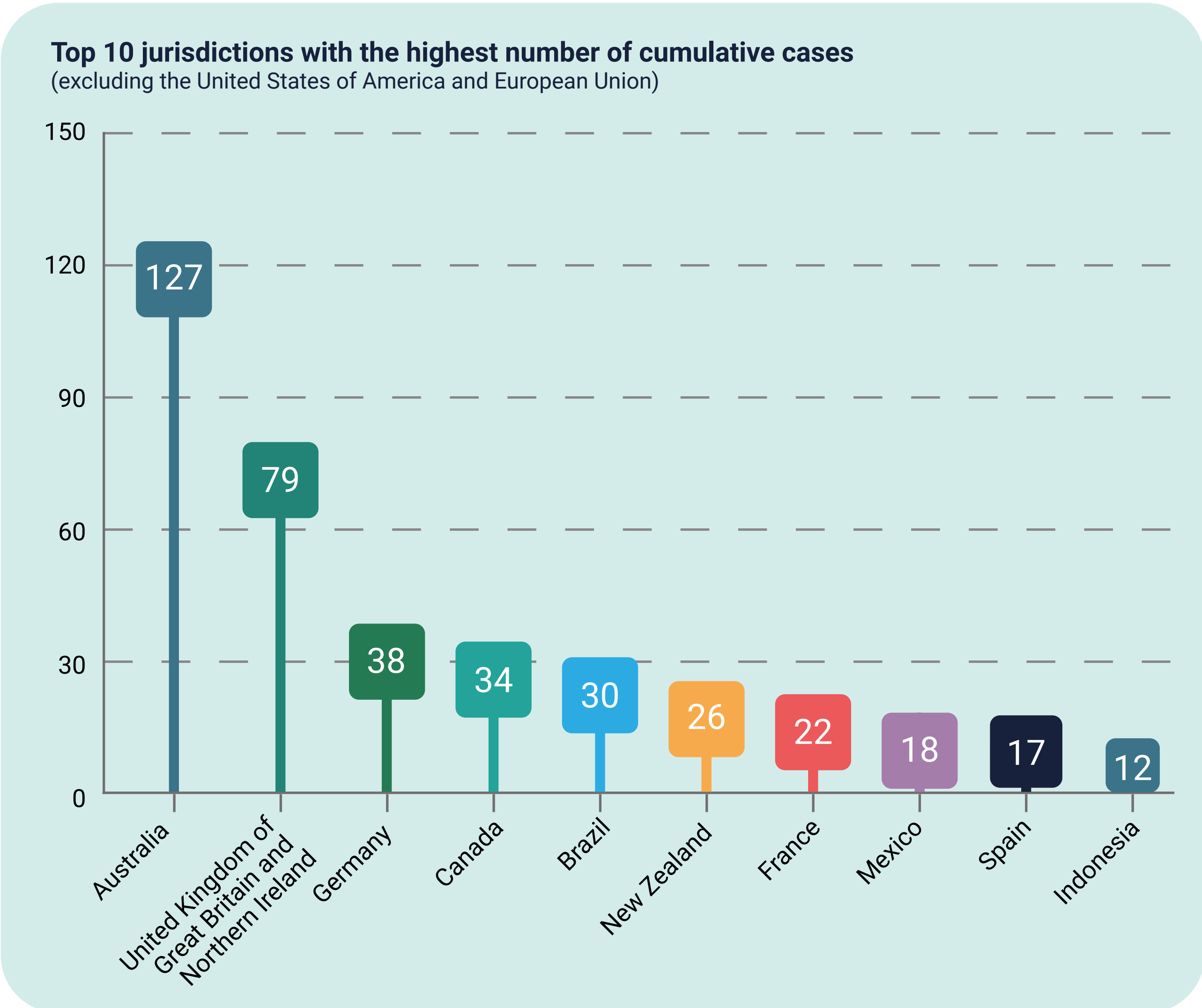
Note: UNFCCC cases refer to non-compliance procedures under UNFCCC.

Figure 5 shows the 10 jurisdictions, excluding the United States of America and the European Union, with the highest number of cases, which are (in descending order) Australia, the United Kingdom, Canada, Brazil, New Zealand, Germany, France, Spain, Mexico and India.[12]

While cases in the United States of America still represent an overwhelming majority of cases globally, the overall percentage of cases outside the United States of America is increasing. In the 2017 Litigation Report, cases in the United States of America represented 74 per cent of the total. In 2020, it was 77 per cent and in 2022, it was 70 per cent.

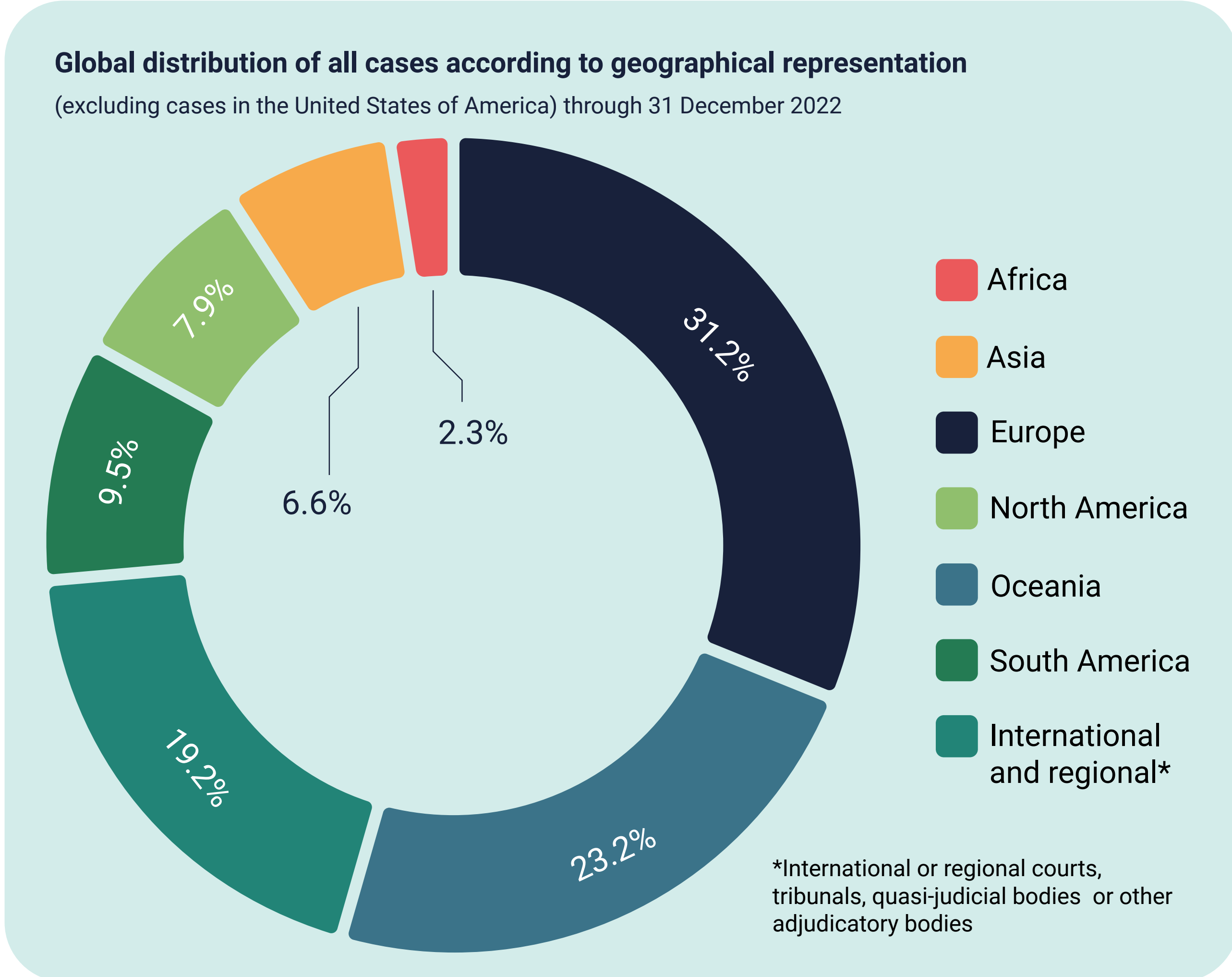
Figure 6 illustrates that, excluding cases in the United States of America, Europe as a region has the highest percentage of cases with 31.2 per cent. Oceania represents 23.2 per cent of the cases. International or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies represent 19.2 per cent of the global cases. South America has 9.5 per cent

Figure 5.



12 The likelihood that climate litigation will be filed in a particular country depends on a range of factors that include the country's legal culture, whether unsuccessful plaintiffs must pay the defendants' costs, the degree of frustration over governments' actions or inactions on climate change, how frequent, extensive, and damaging climate-driven physical losses are becoming, and the existence of regulatory frameworks and judicial precedent that establish enforceable climate-related rights and obligations.

Figure 6.



(Global Change Data Lab 2015)

Note: This figure has been developed using the regional definitions as contained in Our World in Data. The category "International and regional", as noted elsewhere in this report, refers to cases brought before international or regional courts, tribunals, quasi-judicial bodies or other adjudicatory bodies.

of the cases while North America has 7.9 per cent. There is currently no domestic climate litigation in the Caribbean. Asia and Africa still have the lowest representation with 6.6 per cent and 2.3 per cent respectively. As noted in the introduction, some regions remain underrepresented due to gaps in the current research. As the Sabin Center's Network develops, it is likely that these numbers will change.

Litigation in the Global South represents a small but growing percentage of global climate litigation, and these cases are analysed here along with cases from the Global North. While the definition of Global South remains contested, the term is widely used in the context of multilateral debate about the transformation of the global order, especially in reference to emerging economies (Gray and Gills 2016).

According to the Climate Change Litigation databases, there have been 114 cases in the Global South, 421 in the Global North (or 1,943 cases including the United States of America) and 127 in international and regional courts, tribunals and adjudicatory bodies (which can include plaintiffs from the Global North and Global South). As depicted in Figure 7, if considering the cases in the United States of America, cases in the Global North represent 89 per cent of the total number of climate litigation cases. Cases in the Global South amount to 5.2 per cent while international and regional cases amount to 5.8 per cent. As shown in Figure 8, excluding the United States cases from the number of cases in the Global North, the percentage share of cases in the Global South accounts for 17.2 per cent of cases.

Figure 7.

Cumulative percentage of cases according to geographical representation
(cases in the Global South versus cases in the Global North including cases from the United States of America) through 31 December 2022

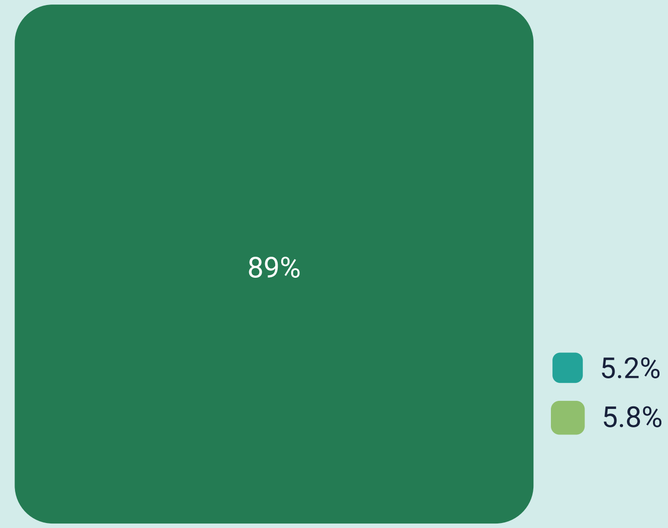
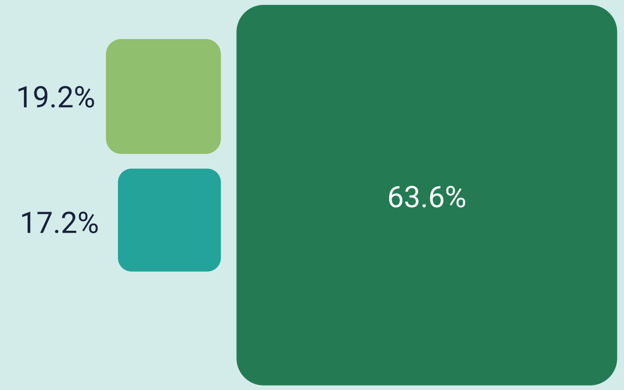


Figure 8.

Cumulative percentage of cases according to geographical representation
(cases in the Global South versus cases in the Global North excluding the United States of America) through 31 December 2022



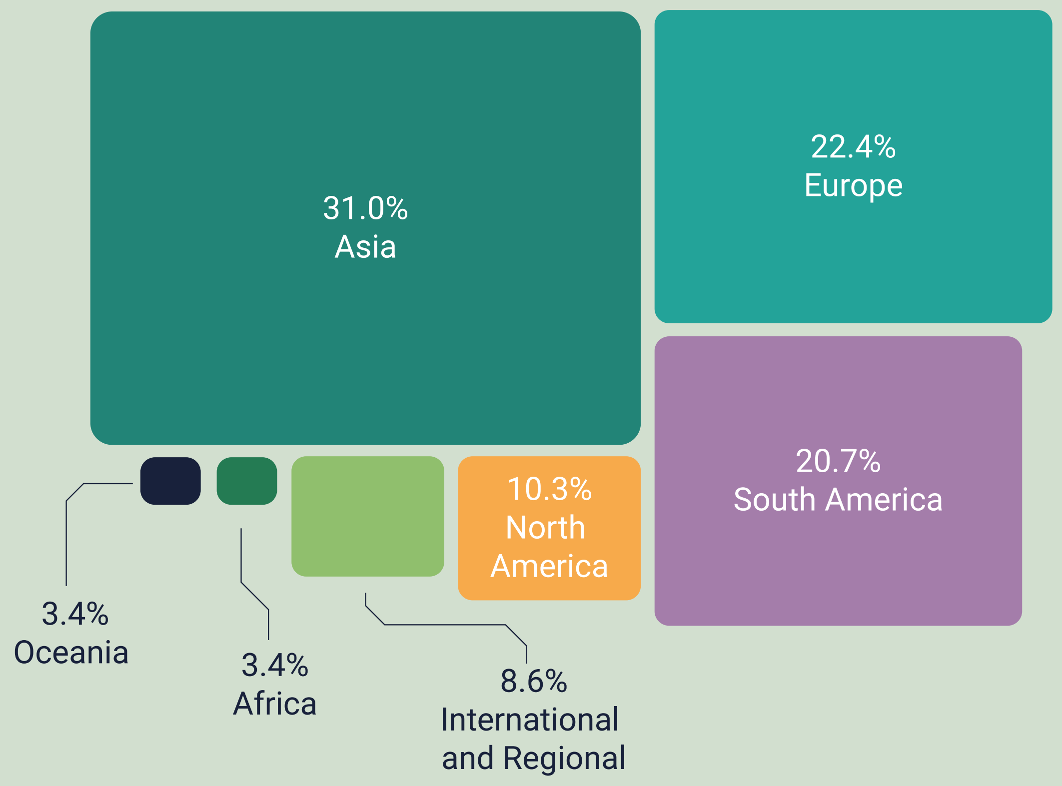
Legend: Global North | Global South | International and regional jurisdictions

Box 2: Changes in the data set since the launch of the Peer Review Network of Global Climate Litigation

Since the launch of the Network in 2021, the Sabin Center has added 58 cases to the database which were filed prior to the publication of the 2020 status report. As these cases were added to the database after the 2020 Litigation Report was published, they were not analysed in that report. These cases are included in the analysis of the present report and represent an ongoing effort to fill the gaps in the geographic representation in the database. Of these, as Figure 9 shows, 18 cases come from Asia, 13 from Europe, 12 from South America, 6 from North America, 2 from Africa, 2 from Oceania, and 5 from international and regional courts, tribunals and adjudicatory bodies.

Figure 9.

Regional distribution of pre-2020 backlog cases[13]



Cases identified here have been filed between 2009 and 1 July 2020, the cut-off date for cases examined in the 2020 Litigation Report.

This box summarizes some highlights that relate to this data set specifically. The analysis is divided by geographical region rather than by topic, as is the rest of the report, to show the expansion in the database's geographical coverage.

A significant proportion of pre-2020 cases from Asia were challenges brought by the Government of Indonesia against palm oil, mining and logging companies for the destruction of peatland ecosystems. In particular, six cases filed between 2012 to 2019 establish the Indonesian Government's right to sue palm oil producers for GHG emissions and loss of carbon sinks from peatland destruction, as well as the actual cost to restore the ecosystem to its original state (*Minister of Environment v. PT Kalista Alam* 2017; *Ministry of Environment and Forestry v. PT Jatim Jaya Perkasa* 2018; *Ministry of Environment and Forestry v. PT Palmina Utama* 2018; *Ministry of Environment and Forestry v. PT Arjuna Utama Sawit* 2020; *Ministry of Environment and Forestry v. PT Asia Palem Lestari* 2021; *Ministry of Environment and Forestry v. PT Rambang Agro Jaya* 2021).[13] In these cases, climate damages arising from GHG emissions were calculated by assigning a numerical value to the cost of emitting a unit of carbon, then calculating the units of carbon emitted by a corporation's actions. In *Shrestha v. Office of the Prime Minister et al.* (2018) Nepal's Supreme Court ruled that climate change impaired the petitioner's constitutional rights to a clean and healthy environment and a dignified life and ordered the Government to enact a new climate law.[14]

Pre-2020 cases from South America focused largely on the global and local costs of resource extraction. In Ecuador, in 2020, gas flaring was declared unlawful because it violates Ecuadorians' rights to a healthy environment and health as well as Ecuador's international climate commitments (*Herrera Carrion et al. v. Ministry of the Environment et al. [Caso Mecheros]* 2021).[15] In Colombia, in 2016, the Constitutional Court ruled that:

(i) The Colombian Government's failure to protect Indigenous and Afro-descendent communities from river pollution from mining violated their fundamental rights

(ii) The river in question had legal personhood

(iii) The Government needed to consider climate change in future mining and energy policy decisions (*Atrato River Decision T-622/16* 2016)[16]

In 2017, that same court ruled that diverting a river for mining violated the Wayúu Indigenous community's right to water, health and food sovereignty, in part because climate change had already impacted the river's water supply, and conducting mining activities in a climate-vulnerable region was likely to cause significant harm. The court ordered the mining company to pay compensation and begin mitigation and correction efforts (*Decision SU-698/17* 2017).[17] In 2020, the Colombian Government's issuing of mining permits was declared impermissible when climate change already threatened ecosystem health and water security. The Constitutional Court ordered the mining activities to be halted immediately (*Combeima River Case* 2020).[18]

13 *Minister of Environment v. PT Kalista Alam, Supreme Court of the Republic of Indonesia*, Decision No. 12/PDT.G/2012/PN.MBO, 18 April 2017 (Indonesia).
Ministry of Environment and Forestry v. PT Jatim Jaya Perkasa, Supreme Court of the Republic of Indonesia, Decision No. 108/Pdt.G/2015/PN.Jkt.Utr., 28 June 2018 (Indonesia).
Ministry of Environment and Forestry v. PT Palmina Utama, Banjarmasin Court of Appeal, Decision No. 48/PDT/2018/PT.BJM, 15 August 2018 (Indonesia).
Ministry of Environment and Forestry v. PT Arjuna Utama Sawit, Supreme Court of the Republic of Indonesia, Decision No. 213/Pdt.G/LH/2018/PN.Plk, 10 December 2020 (Indonesia).
Ministry of Environment and Forestry v. PT Asia Palem Lestari, District Court of North Jakarta, Decision No. 607/Pdt.G-LH/2019/PN.Jkt.Utr, 5 January 2021 (Indonesia).
Ministry of Environment and Forestry v. PT Rambang Agro Jaya, District Court of Central Jakarta, Decision No. 445/Pdt.G/2019/PN.Jkt.Pst, 11 January 2021 (Indonesia).

14 *Shrestha v. Office of the Prime Minister et al.*, Supreme Court of Nepal, Order 074-WO-0283, 25 December 2018 (Nepal).

15 *Herrera Carrion et al. v. Ministry of the Environment et al. (Caso Mecheros)*, Provincial Court of Justice of Sucumbío, Juicio No. 21201202000170, 29 July 2021 (Ecuador).

16 *Atrato River Decision T-622/16*, Constitutional Court of Colombia, 10 November 2016 (Colombia).

17 *Decision SU-698/17, Constitutional Court of Colombia*, 28 November 2017 (Colombia).

18 *Combeima River Case, Administrative Tribunals of Colombia*, 73001-2331-000-2011-00611-03, 14 September 2020.

Cases pre-2020 from North America focused largely on the national energy sector and climate change policy. In Canada, an NGO challenged the Canadian Government's approval of a new liquefied natural gas facility because (among other things) the initial environmental impact assessment (EIA) did not consider GHG emissions for the entire lifetime of the facility (*SkeenaWild Conservation Trust v. Government of Canada* 2019).[19] That case was withdrawn after the project investor walked away from the project.

Cases pre-2020 from Europe included citizen and NGO challenges to inaction on Paris Agreement commitments. In France and the United Kingdom, climate activists faced criminal charges for actions taken during climate protests *(R. v. Brown [Extinction Rebellion protest, London City Airport]* 2022).[20] In ADP Group (Paris Airports) v. Climate Activists (2021), activists who illegally entered the tarmac at Paris Charles de Gaulle Airport and halted airport operations were acquitted because their actions were taken in a "state of necessity" to warn of future danger, namely climate change.[21]

Cases from international and regional bodies included challenges to the European Union's environmental legislation by impacted parties in Southeast Asia. Two pre-2020 cases currently before the World Trade Organization Dispute Settlement Body have challenged European Union regulations on "high-risk" biofuels on the basis that they unnecessarily advantage intra-European Union producers and disadvantage Indonesian and Malaysian palm oil producers, in violation of international trade agreements (*DS-593: European Union – Certain Measures Concerning Palm Oil and Oil Palm Crop-based Biofuels* 2019; DS-600: *European Union and Certain Member States – Certain Measures Concerning Palm Oil and Oil Palm Crop-Based Biofuels* 2021).[22] The measures taken by the European Union were implemented to pursue policy objectives of climate change mitigation, environmental protection, preserving biodiversity and ensuring energy security and sustainability.

The two cases from Oceania both originated in New Zealand. One case did not allow the urgency of the climate crisis as a defence to criminal liability when lawful protest activities were available to climate activists (*Police v. Hanafin* 2020).[23] Another case challenged a local government's decision not to sign a "Local Leaders Climate Change Declaration", an agreement to take aggressive climate change action and compel the national Government to do the same. The High Court of New Zealand ruled that the local government's decision not to sign the pledge was unreasonable in light of the local impacts of climate change and ordered the government to reconsider its decision (*Hauraki Coromandel Climate Action Incorporated v. Thames-Coromandel District Council* 2020).[24]

In South Africa, the High Court rejected a case by the City of Cape Town seeking authorization to purchase renewable electricity from independent power producers without obtaining approval from the Minister of Mineral Resources and Energy. That case was rejected because it was determined to be an intergovernmental dispute that should be settled outside of court (*The City of Cape Town v. National Energy Regulator of South Africa and Minister of Energy* 2020).[25]

19 *SkeenaWild Conservation Trust v. Government of Canada*, Federal Court of Canada, Application No. T-1836-16, 27 October 2016 (Canada).

20 *R. v. Brown (Extinction Rebellion protest, London City Airport)*, Court of Appeal (Criminal Division) of England and Wales, Case No. [2022] EWCA Crim 6, 14 January 2022 (United Kingdom of Great Britain and Northern Ireland).

21 *ADP Group (Paris Airports) v. Climate Activists*, Court of First Instance of Bobigny, Tribunal Correctional, 12 November 2021 (France).

22 *DS-593: European Union – Certain Measures Concerning Palm Oil and Oil Palm Crop-based Biofuels*, World Trade Organization Dispute Settlement Body, Doc. No. WT/DS593/1, 9 December 2019 (World Trade Organization).
DS-600: European Union and Certain Member States – Certain Measures Concerning Palm Oil and Oil Palm Crop-Based Biofuels, World Trade Organization Dispute Settlement Body, Doc. No. WT/DS600/1, 15 January 2021 (World Trade Organization).

23 *Police v. Hanafin*, District Court of New Zealand, Decision No. CRI-2019-076-001503, 13 November 2020 (New Zealand).

24 *Hauraki Coromandel Climate Action Incorporated v. Thames-Coromandel District Council*, High Court of New Zealand, Case No. CIV-2019-419-173, NZHC 3228, 8 December 2020 (New Zealand).

25 *The City of Cape Town v. National Energy Regulator of South Africa and Minister of Energy*, High Court of South Africa, Case No. 51765/17, 11 August 2020 (South Africa).

Part 3: The state of climate change litigation

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Part 3: The state of climate change litigation

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This section describes and summarizes the status of climate change litigation throughout the world. It discusses key cases and how they are thematically linked to larger categories of climate cases. It identifies six important categories into which most cases can be placed and discusses issues that both arise in and run through these cases. Climate cases to date often fall into one or more of six categories:

- **(i)** The use of "climate rights" in climate litigation
- **(ii)** Domestic enforcement
- **(iii)** Keeping fossil fuels and carbon sinks in the ground
- **(iv)** Corporate liability and responsibility
- **(v)** Climate disclosures and greenwashing
- **(vi)** Failure to adapt and the impacts of adaptation[1]

I. The use of "climate rights" in climate litigation

One of the most visible categories of climate cases includes actions asserting that insufficient climate mitigation or adaptation violates plaintiffs' rights, including the rights to life, health, food, water, liberty, family life, a healthy environment, a safe climate and more. Here, this category is referred to as "climate rights". Climate rights encompass the ways in which national constitution, human rights law and other laws in general, imbue individuals and communities with rights to climate mitigation and adaptation action. It refers to both international and domestic commitments made to ensure that people will enjoy a safe and stable climate as well as other rights that do not explicitly focus on climate but have an impact in addressing climate change. These rights are variously known as human rights, environmental rights and human rights obligations related to the environment. As women are disproportionately impacted by climate change, women's rights remain a key category of human rights that directly fulfils Sustainable Development Goal 5 on gender equality and the empowerment of women. Obligations pertaining to climate rights fall into three main categories: substantive obligations, procedural obligations, and obligations relating to persons and groups in vulnerable situations (United Nations 2022).

> **"Cases brought in domestic forums have argued that climate rights emerge from existing constitutional and fundamental rights under domestic law, and often relate to international obligations under the Paris Agreement."**

Cases brought in domestic forums have argued that climate rights emerge from existing constitutional and fundamental rights under domestic law, and often relate to international obligations under the Paris Agreement. The 2017 and 2020 Litigation Reports highlighted climate rights cases in Austria, Australia, Brazil, Canada, Colombia, India, Netherlands, Norway, Pakistan, Peru, Philippines, the Republic of Korea, Switzerland and the United States of America. Several of these cases are still pending as at 31 December 2022. However, many cases are still not brought to the forefront as financial challenges, intimidation, lack of know-how and other barriers remain in place. These barriers are especially harmful for vulnerable groups including Indigenous Peoples, women and those from a lower socioeconomic status, the majority of whom are women. The 2020 Litigation Report also highlighted a group of cases in international forums asserting that climate change violates international human rights. Since 2020, more claims have been brought and decisions have been reached in several instances. This section is divided between international and domestic climate rights cases.

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1 As the analysis in this Part 3 indicates, several cases demonstrate features of more than one trend and thus appear in multiple sections.

A. International climate rights cases

The number of climate rights claims before and decisions by international adjudicative bodies has been growing. While still a small percentage of cases, these claims build on a body of soft law, including statements from the Inter-American Court of Human Rights (IACtHR), HRC and the United Nations General Assembly.

In October 2021, HRC adopted a historic resolution (A/HRC/RES/48/13) recognizing the human right to a clean, healthy and sustainable environment. HRC recognized that climate change, the environmental crisis and biodiversity loss have negative impacts on the enjoyment of all human rights, "including the rights to life, to the enjoyment of the highest attainable standard of physical and mental health, to an adequate standard of living, to adequate food, to housing, to safe drinking water and sanitation and to participation in cultural life, for present and future generations". In July 2022, Member States of the United Nations General Assembly adopted a landmark resolution (A/RES/76/300) that recognizes that a clean, healthy and sustainable environment is a human right. While the resolution is not legally binding, it can give rise to constitutional and legal changes that could positively impact the environment and human well-being. Recognizing the right to a healthy environment at the international level is likely to reinforce rights-based claims before adjudicatory bodies.

Similar developments on the recognition of a right to a healthy environment are also taking place at the regional level. For example, the Parliamentary Assembly of the Council of Europe has presented a draft of an additional protocol to the European Convention on Human Rights (ECHR) which would anchor the right to a safe, clean, healthy and sustainable environment and make such a right enforceable in law in all countries which ratified it (United Nations 2021).

i. Cases at the United Nations

To date, there have been several petitions filed with various United Nations bodies.

In October 2021, the United Nations Committee on the Rights of the Child rejected a petition filed by 16 children in *Sacchi, et al. v. Argentina, et al.* (2021), which alleged that Argentina, Brazil, France, Germany and Türkiye violated their rights under the United Nations Convention on the Rights of the Child by making insufficient cuts to GHG emissions.[2] The petitions were dismissed due to a failure to exhaust domestic remedies. Nonetheless, the findings and legal reasoning of the United Nations Committee on the Rights of the Child provide valuable guidance on children's rights in the context of climate change. First, the United Nations Committee on the Rights of the Child found that the potential harm of the States' acts or omissions regarding their carbon emissions was reasonably foreseeable to the States. Second, it affirmed that the States' carbon emissions actively contribute to the harmful effects of climate change and that these are not limited to emissions within these States' boundaries. Third, it concluded that the petitioners had pleaded sufficient facts to establish that the violation of their rights under the United Nations Convention on the Rights of the Child as a result of the States' carbon emissions was reasonably foreseeable and that they have personally experienced significant harm (Tigre and Lichet 2021). After the dismissal of the petition, the same children submitted a petition to the United Nations Secretary-General asking him to declare a climate emergency, which would mobilize a United Nations comprehensive response to the climate emergency and activate a crisis management team to oversee immediate and comprehensive global action on climate change (Sacchi *et al.* 2021). The petition is still pending as at 31 December 2022.

2 *Sacchi, et al. v. Argentina, et al.*, United Nations Committee on the Rights of the Child, Communication No. 104/2019 (Argentina), Communication No. 105/2019 (Brazil), Communication No. 106/2019 (France), Communication No. 107/2019 (Germany), Communication No. 108/2019 (Türkiye), 12 October 2021 (United Nations Committee on the Rights of the Child).

Box 3: Decision by the United Nations Human Rights Committee on the Torres Strait Islanders Petition

In September 2022, the United Nations Human Rights Committee delivered a landmark decision in *Daniel Billy and others v. Australia (Torres Strait Islanders Petition)* (2022), finding that the Australian Government was violating its human rights obligations to the Indigenous Torres Strait Islanders through climate change inaction.[3] The Committee found that Australia's failure to adequately protect Indigenous Torres Strait Islanders against adverse impacts of climate change violated their rights to enjoy their culture and be free from arbitrary interferences with their private life, family and home. For the first time, a United Nations body had found that a country violated international human rights law through inadequate climate policy. The decision also represents the first time that Indigenous Peoples' right to culture was found to be at risk from climate impacts. The United Nations Human Rights Committee recognized that climate change was currently impacting the claimants' daily lives and that, to the extent that their rights are being violated, Australia's poor climate record was a violation of their right to family life and right to culture. The decision also specifically called on Australia to adopt significant climate adaptation measures.

Petitions to United Nations bodies do not require an official response. However, they can lead to statements from the United Nations special procedures that are relevant for climate litigation. To date, there has not been any formal action in response to a petition that was brought to the United Nations special procedures by five tribes in Louisiana and Alaska, United States of America. The petition has highlighted the negative impacts of climate change and claimed that the Government of the United States of America has violated their human rights in failing to address climate displacement (*Rights of Indigenous People in Addressing Climate-Forced Displacement* 2020).[4]

In October 2021, a petition was submitted to the United Nations special procedures by Environmental Justice Australia on behalf of several young Australians. The petition relied on the climate vulnerability of young people, First Nations people and people with disabilities, and argued that climate change exacerbates existing inequalities and directly undermines their health and cultural rights (*Environmental Justice Australia (EJA) v. Australia* 2021).[5] It asked the Special Rapporteurs to seek an explanation from Australia on how:

(i) The State's climate inaction is consistent with its human rights obligations

(ii) The current conduct is compatible with the human rights of young Australians and a pathway towards limiting the temperature increase to 1.5°C above pre-industrial levels

(iii) Its current NDC has involved young people in Australia in the process of developing NDC and whether the State will establish a permanent forum to include the participation of young people from impacted communities

In addition, the complaint called on the Special Rapporteurs to urge Australia to set a 2030 emissions reduction target consistent with its human rights obligations.

3 *Daniel Billy and others v. Australia (Torres Strait Islanders Petition)*, United Nations Human Rights Committee, CCPR/C/135/D/3624/2019, 23 September 2022 (United Nations Human Rights Committee).

4 *Rights of Indigenous People in Addressing Climate-Forced Displacement*, United Nations Special Rapporteurs, Ref. AL USA 16/2020, 15 September 2020 (United Nations).

5 *Environmental Justice Australia (EJA) v. Australia*, United Nations Special Rapporteurs, 25 October 2021 (United Nations).

In *The Planet v. Bolsonaro* (2021), a communication was filed to the Office of the Prosecutor of the International Criminal Court (ICC) in 2021 requesting an investigation into former Brazilian President Jair Bolsonaro for his role in crimes against humanity resulting from ongoing deforestation and related activities in the Amazon rainforest.[6] The communication alleged that former President Bolsonaro has promoted and facilitated a widespread attack on the Amazon biome and those who defend and depend upon it, which represents a clear and extant threat to humanity itself. The complaint argued that global climate security is dependent on the Amazon and its key role in regulating global temperatures and weather patterns, and that the severe damage to the functions of the Amazon biome caused by deforestation, conversion of deforested land to cattle ranching and vast intentional forest fires has disrupted this critical ecosystem, turning it from a carbon sink to a carbon source. The Office of the Prosecutor must first conduct an analysis of information to determine whether the statutory threshold of "a reasonable basis to proceed" to start an investigation is met, according to ICC rules (ICC 2016). If there is an investigation, it would be the first time that an investigation relating to crimes against humanity would be based on alleged environmental and climate harm.

Box 4: Initiatives to seek advisory opinions on climate change from international courts

International adjudicating bodies are not only mandated to settle disputes, but also to issue advisory opinions, which may be of great value in the development of international law. Two requests for advisory opinions of international courts are currently in progress. In 2022, the Republic of Vanuatu initiated an international campaign to seek an advisory opinion on climate change from the International Court of Justice. The draft zero of the request for advisory opinion (A/77/L.58), which is currently under negotiation and may be subject to changes, includes the following questions:

- (a) What are the obligations of States under international law to ensure the protection of the climate system and other parts of the environment for present and future generations
- (b) What are the legal consequences under these obligations for States where they, by their acts and omissions, have caused significant harm to the climate system and other parts of the environment, with respect to:
  - (i) States, including, in particular, small island developing States, which due to their geographical circumstances and level of development, are injured or specially affected by or are particularly vulnerable to the adverse effects of climate change?
  - (ii) Peoples and individuals of the present and future generations affected by the adverse effects of climate change?

An International Court of Justice advisory opinion may be issued at the request of the United Nations General Assembly, the Security Council or by other United Nations organs and specialized agencies. The Vanuatu campaign is pursuing the United Nations General Assembly route, which requires support from the majority of United Nations members present and voting (Savaresi, Kulovesi and van Asselt 2021).

6 *The Planet v. Bolsonaro*, ICC, 12 October 2021 (ICC).

In addition, Antigua and Barbuda and Tuvalu signed an agreement for the establishment of the Commission of Small Island States on Climate Change and International Law, to seek an advisory opinion from the International Tribunal for the Law of the Sea (ITLOS) (De Shong 2021). The Climate Commission Agreement is open to accession by any other members of the Alliance of Small Island States (Freestone, Barnes and Akhavan 2021). ITLOS can give an advisory opinion on a legal question on the interpretation and application of the United Nations Convention on the Law of the Sea to climate change, which could include, for example, questions on sea level rise and ocean acidification and deoxygenation (Cruz Carrillo 2021). The advisory jurisdiction of ITLOS can be triggered by three elements:

1. An international agreement related to the purposes of United Nations Convention on the Law of the Sea clearly providing for the submission to the tribunal of a request for an advisory opinion
2. The request must be transmitted to ITLOS by an authorized body or per that agreement
3. The request must be premised on a legal question

In December 2022, the co-chairs of the Commission of Small Island States on Climate Change and International Law submitted a request for an advisory opinion from ITLOS (*Request for an Advisory Opinion submitted by the Commission of Small Island States on Climate Change and International Law* 2022).[7] The Commission referred the following legal questions to ITLOS:

"What are the specific obligations of State Parties to the United Nations Convention on the Law of the Sea (the 'UNCLOS'), including under Part XII:

- (a) to prevent, reduce and control pollution of the marine environment in relation to the deleterious effects that result or are likely to result from climate change, including through ocean warming and sea level rise, and ocean acidification, which are caused by anthropogenic greenhouse gas emissions into the atmosphere?
- (b) to protect and preserve the marine environment in relation to climate change impacts, including ocean warming and sea level rise, and ocean acidification?"

ii. Regional cases

At the regional level, climate cases are proceeding in several venues. These cases are discussed below.

a. Cases before the Inter-American System of Human Rights

The 2020 Litigation Report noted that IACtHR issued advisory opinion OC-23/17 in 2019, in response to a request from Colombia, in which the court concluded that the right to a healthy environment is a human right under the American Convention on Human Rights (*A Request for an Advisory Opinion from the Inter-American Court of Human Rights Concerning the Interpretation of Article 1(1), 4(1) and 5(1) of the American Convention on Human Rights* 2017).[8] The opinion addressed climate change throughout, acknowledging that climate change is widely understood to interfere with the enjoyment of human rights and articulating a State's extraterritorial responsibility for environmental damage and climate change (Tigre and Urzola 2021).

In 2021, the Inter-American Commission of Human Rights (IACHR) and the Office of the Special Rapporteur on Economic, Social, Cultural, and Environmental Rights, relying on IACtHR's advisory opinion, jointly adopted resolution No. 3/21, entitled Climate Emergency: Scope of Inter-American human rights obligations (IACHR 2021a). The resolution's purpose is to systematize States' human rights

7 *Request for an Advisory Opinion submitted by the Commission of Small Island States on Climate Change and International Law*, ITLOS, Case No. 31/2022, 12 December 2022 (ITLOS).

8 *A Request for an Advisory Opinion from the Inter-American Court of Human Rights Concerning the Interpretation of Article 1(1), 4(1) and 5(1) of the American Convention on Human Rights*, IACtHR, Advisory Opinion OC-23/17, 15 November 2017 (IACtHR).

obligations in the context of the climate crisis to ensure that public policy decisions are made according to a rights-based approach. The resolution calls on States to comply with standards of climate action that particularly protect the rights of the most vulnerable and calls on States to "move towards a clean and just energy transition". The resolution encourages companies to "adjust their behaviour and operations to the norms of the business and human rights regime" and "adopt plans to reduce GHG emissions" and make them public (IACHR 2021a). This duty to adopt mitigation plans covers products and services, subsidiaries and suppliers.

In the 2021 *Petition to the Inter-American Commission on Human Rights Seeking to Redress Violations of the Rights of Children in Cité Soleil, Haiti* (2021), several Haitian children petitioned IACHR to investigate human rights violations stemming from waste disposal in their residential district (IACHR 2021b).[9] The petition includes a discussion of climate change's intensification of harms to children through environmental displacement and exacerbation of waterborne diseases. Petitioners have alleged violations of the provisions of the American Convention on Human Rights on the rights of the child (article 19), the right to dignity (under the right to privacy, article 11), the right to live in a healthy environment (articles 4 and 26), and the right to judicial protection (article 25). IACHR is expected first to decide whether to assert jurisdiction.

b. Cases before the East African Court of Justice

In November 2020, four civil society organizations filed a suit against the Governments of the United Republic of Tanzania and Uganda in the East African Court of Justice, seeking an injunction to stop the construction of the East African Crude Oil Pipeline. In *Center for Food and Adequate Living Rights et al. v. Tanzania and Uganda* (2020), plaintiffs have alleged that the Governments, without objection from the Secretary-General of the East African Community who is responsible for oversight of the East African Community Treaty, have signed agreements to build the pipeline without proper environmental, social, human rights and climate impact assessments. The pending claim arises under Ugandan national law, and the East African Community Treaty and its protocols.[10]

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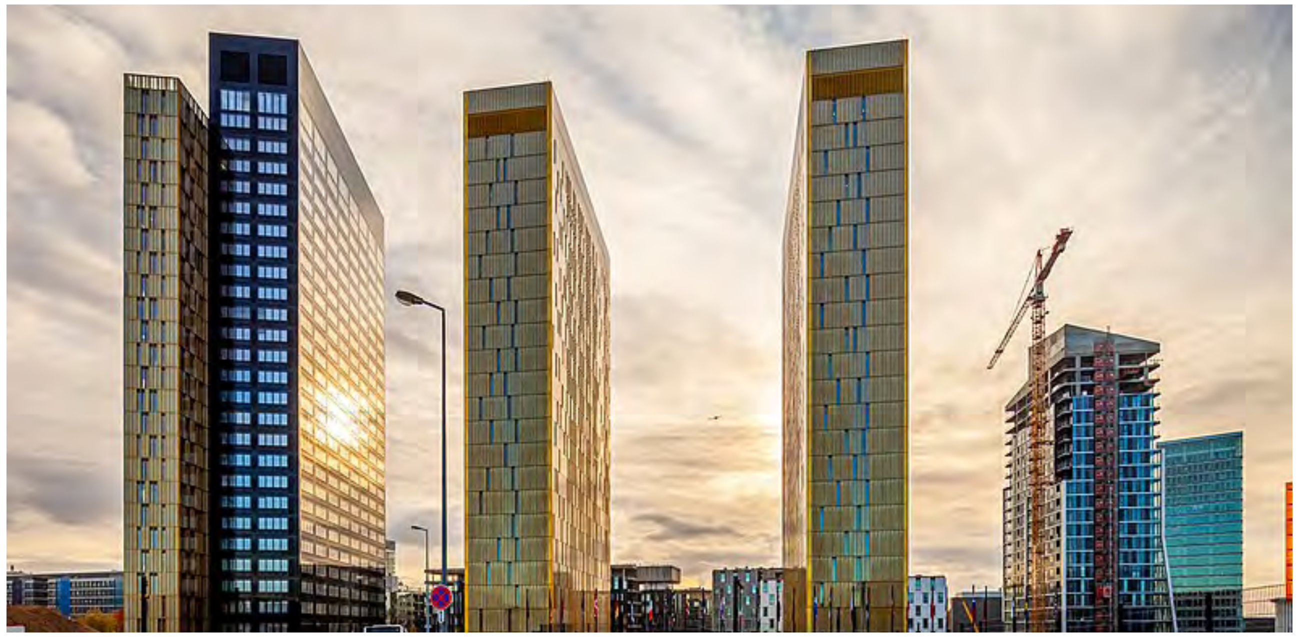
9 *Petition to the Inter-American Commission on Human Rights Seeking to Redress Violations of the Rights of Children in Cité Soleil*, Haiti, IACHR, 4 February 2021 (IACHR).

10 *Center for Food and Adequate Living Rights et al. v. Tanzania and Uganda*, East African Court of Justice, 6 November 2020 (East African Court of Justice).



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c. Cases before European regional courts

Several cases have recently been filed under European regional courts. Cases under the Court of Justice of the European Union (CJEU) have been met with limited success and were dismissed on procedural grounds. Some pending claims at the European Court of Human Rights (ECtHR) as at 31 December 2022 are discussed below.

Court of Justice of the European Union

CJEU has explicit and far-reaching review powers to interpret the law of the European Union and ensure it is applied in the same way across the member States of the European Union, including the power to annul legislative acts (European Union 2007; European Union 2008). CJEU has so far had two climate cases, and both were dismissed due to lack of standing (*Peter Sabo et al. v. European Parliament and Council of the European Union* 2020).[11] In *Armando Ferrão Carvalho and Others v. the European Parliament and the Council* (2021) (the People's Climate Case), the applicants (families in the agricultural or tourism sectors in several European Union and non-European Union countries) challenged European Union legislation adopted to enable it to meet its GHG emissions reduction targets, which, they argued, were insufficient to protect their lives, livelihoods and human rights from the impacts of climate change.[12] The applicants in Carvalho argued that the violation of climate-related human rights is so unique that the strict standing test (that applicants need to show an individual concern particular to them or their group) (*Plaumann & Co. v. Commission of the European Economic Community* 1963; Hartmann and Willers 2021)[13] should be altered (Winter 2020). However, CJEU rejected those arguments and dismissed the claim, concluding that since everyone is impacted by climate change in one unique way or another, the applicants could not demonstrate that they were individually impacted by the European Union's climate policy (Tigre 2022a). CJEU's approach prevents individuals and environmental groups from challenging European Union law measures of general application, even when human rights are affected (Hartmann and Willers 2021).

In *Ville de Paris and Others v. European Commission* (2022), the City of Paris, the City of Brussels and the

11 The European Union Biomass case was highlighted in the 2020 Litigation Report.
Peter Sabo et al. v. European Parliament and Council of the European Union, CJEU, Case No. T-141/19, Order ECLI:EU:T:2020:179, 6 May 2020 (European Union).

12 *Armando Ferrão Carvalho and Others v. the European Parliament and the Council*, CJEU, Case No. T-330/18, 25 March 2021 (European Union).

13 *Plaumann & Co. v. Commission of the European Economic Community*, CJEU, Case No. 25/62, Order ECLI:EU:C:1963:17, 15 July 1963 (European Union).

Municipality of Madrid brought an action against the European Commission, challenging a regulation establishing a new procedure for testing the real driving emissions of certain motor vehicles. The cities argued that the regulation would prevent them from imposing restrictions on the circulation of passenger vehicles in relation to their air pollutant emissions. In 2018, the General Court partially upheld the action, prompting an appeal to CJEU. In 2022, CJEU handed down its decision in that appeal, ruling in favour of the European Commission.[14] The ruling clarifies requirements for standing under primary law of the European Union to challenge a Commission regulation. CJEU held that the General Court had erred when it stated that the cities were prevented from exercising their powers to regulate the circulation of passenger vehicles to reduce pollution because the cities did not have a "direct concern".

European Court of Human Rights

ECtHR has not yet ruled on the implications of climate change for the enjoyment of the rights enshrined in ECHR. However, 12 climate cases have recently been brought before ECtHR. In these, applicants argue that the Member States of the Council of Europe have violated some of the provisions of ECHR when considered in light of the Paris Agreement. All cases rely on the respondent States' positive obligations concerning the right to life (article 2) and the right to respect for private and family life (article 8). The cases further make discrimination claims (article 14), alleging that the characteristics of their group or their personal circumstances are such that they will suffer particularly from the impacts of climate change.[15]

Three cases (*Duarte Agostinho, KlimaSeniorinnen,* and *Greenpeace Nordic*) have already been communicated to State parties, meaning they were considered admissible at the preliminary stage. The court can still assess admissibility issues at a later stage. Four climate cases (*Duarte Agostinho, KlimaSeniorinnen, Greenpeace Nordic,* and *Carême*) have been considered "impact cases" and deemed a priority for hearing. In April and June 2022, respectively, ECtHR announced that the Grand Chamber would deal with KlimaSeniorinnen, Carême and Duarte Agostinho. This option can be used when the seven judges decide that the case raises "a serious question affecting the interpretation of the Convention or the Protocols thereto, or where the resolution of a question before the chamber might have a result inconsistent with a judgment previously delivered by the court".[16] This development underlines the high profile the court is giving those cases, which are following a fast track at ECtHR (Schmid 2022).

In *Duarte Agostinho and Others v. Portugal and 32 Other States* (2021), six Portuguese youth filed a complaint against 33 countries alleging that the respondents violated petitioners' human rights by failing to take sufficient action on climate change, and the applicants requested member States of the European Union to take more ambitious domestic action. The applicants alleged that wildfires and increased temperatures affect their human rights and further breach the prohibition of discrimination due to climate change's disproportionate impact on younger generations resulting from the prolonged effects they will suffer.[17] The plaintiffs filed the case directly with ECtHR without first exhausting domestic remedies, based on the urgent needs to address the climate crisis. Two other similar complaints (*De Conto v. Italy and 32 other States* 2021; *Uricchio v. Italy and 32 other States* 2021) were filed against Italy, relying on the same legal grounds and also without first exhausting domestic remedies.[18]

Association of Swiss Senior Women for Climate Protection v. Federal Department of the Environment Transport, Energy and Communications (DETEC) and Others (*KlimaSeniorinnen v. Switzerland*) (2020) was brought by an association of senior women and four individual applicants against Switzerland in November 2020.[19] Their application to ECtHR follows a domestic rejection of the applicants' complaint on the basis that senior women are not uniquely affected by climate change, as detailed below. *Müllner v. Austria* (2021) was lodged against Austria by an individual applicant who suffers from Uhthoff's syndrome, which affects people with multiple sclerosis who suffer when temperatures rise above 25°C. The case was filed after an unsuccessful appeal to the Austrian Supreme Court.[20] In *Greenpeace Nordic and Others v. Norway* (2021), several NGOs and six young climate activists filed a claim against the Norwegian Government, alleging that continued oil exploration by the Norwegian State breaches their fundamental human rights.[21] The case follows a decision by the Norwegian Supreme Court, as explained below. In *Carême v. France* (2022), the Mayor of Grande-Synthe, whose application in *Commune de Grande-Synthe v. France* (2021) was rejected, complained that the Council of State erred in rejecting his action. By claiming that he had no interest in the proceedings even though he was exposed to climate risk caused by insufficient government action, the mayor claimed the Council of State had violated his human rights.[22]

Five additional applications were filed in 2022. For example, in *Soubeste and Others v. Austria and 11 Other States* (2022), young European citizens alleged that their human rights have been adversely affected by climate change, which is driven, to a large extent, by the fossil energy industry.[23] They further contended that the 1994 Energy Charter Treaty, ratified by all 12 respondent States, protects investors in that sector from regulatory changes and gives them access to exorbitant remedies through investor-State dispute settlement (ISDS) mechanisms, thereby inhibiting the respondent States from taking immediate measures against climate change and making it impossible for them to attain the long term temperature goals enshrined in the Paris Agreement. In *Plan B. Earth and Others v. United Kingdom* (2022), applicants alleged that, in breach of its legal obligations arising under the Human Rights Act 1998 and ECHR, the United Kingdom is systematically failing to take practical and effective measures to address the threat from man-made climate breakdown.[24] In *Humane Being v. the United Kingdom* (2022), the applicant alleged that the United Kingdom is in breach of its obligations under ECHR for failing to address the risks of the climate crisis, future pandemics and antibiotic resistance created by factory farming.[25] This application posed novel climate arguments focusing on the danger of agricultural methane emissions and highlighting soy feed consumption in factory farming in the United Kingdom as a key driver of deforestation in the Amazon basin.

14 *Ville de Paris and Others v. European Commission*, CJEU, Case No. C-177/19 P to C-177/19 P, 13 January 2022 (European Union).

15 Ibid.

16 Article 30 of the ECHR.

17 *Duarte Agostinho and Others v. Portugal and 32 Other States*, ECtHR, Query No. 39371/20, 4 February 2021 (ECtHR).

18 *De Conto v. Italy and 32 Other States*, ECtHR, Complaint No. 14620/21, 3 March 2021 (ECtHR).
Uricchio v. Italy and 32 Other States, ECtHR, Complaint No. 14615/21, 3 March 2021 (ECtHR).

19 *Association of Swiss Senior Women for Climate Protection v. Federal Department of the Environment Transport, Energy and Communications (DETEC) and Others*, Federal Supreme Court of Switzerland, Case No. A-2992/2017, 26 November 2020 (Switzerland).

20 *Müllner v. Austria*, ECtHR, 25 March 2021 (European Court of Human Rights).

21 *Greenpeace Nordic and Others v. Norway*, ECtHR, Application No. 34068/21, 15 June 2021 (ECtHR).

22 *Commune de Grande-Synthe v. France*, Council of State of France, No. 427301, 1 July 2021 (France).
Carême v. France, ECtHR, Application No. 7189/21, 7 June 2022 (ECtHR).

23 *Soubeste and Others v. Austria and 11 Other States*, ECtHR, Case No. 31925/22, 2022 (ECtHR).

24 *Plan B.Earth and Others v. United Kingdom*, ECtHR, 11 July 2022.

25 *Humane Being v. the United Kingdom*, ECtHR, 26 July 2022 (European Court of Human Rights).

B. Domestic climate rights cases

Cases brought in domestic forums have argued that climate obligations emerge from existing constitutional and fundamental rights secured under domestic law. These cases highlight the impact of climate change on human rights and challenge deficiencies of domestic regimes to address climate change. They have relied on:

- **(i)** Human rights
- **(ii)** The right to a healthy environment
- **(iii)** Rights of nature
- **(iv)** A combination of these

i. Human rights

Several cases brought in Europe rely on articles 2 and 8 of ECHR to inform domestic law. These cases often challenge whether a government's mitigation efforts are adequate to meet Paris Agreement commitments or whether particular government policies are consistent with human rights obligations. While several cases are still pending, these strategies have achieved some success. Courts in Belgium and Germany have found that insufficient climate mitigation breaches human rights obligations under ECHR and under the national government's duty of care. Courts have found that governments have failed to take the necessary measures to prevent the harmful effects of climate change or protect human rights to minimize climate risk.

In April 2021, the *German Federal Constitutional Court in Neubauer, et al. v. Germany* (2021) struck down parts of Germany's Federal Climate Protection Act as incompatible with constitutional rights to life and health, among others, because the legislation did not include sufficient provisions for emissions cuts beyond 2030.[26] The court found the legislation's mitigation targets inadequate to protect human rights or to proportionally distribute the global carbon budget between current and future generations. The court concluded that Germany's climate law was effectively "offloading" emissions reduction to future generations in a violation of fundamental freedoms. The court grounded the decision in the State's duty to protect fundamental rights and to minimize a foreseeable and sufficiently serious risk of harm posed by climate change. The court ordered the legislature to set clear provisions for reduction targets from 2031 onward by the end of 2022. A revised Climate Protection Act requiring a reduction of 65 per cent in GHGs from 1990 levels by 2030 was passed in 2021. A new challenge was brought before the Federal Constitutional Court in 2022, arguing that the targets continue to infringe fundamental rights as they still exceed Germany's remaining carbon budget and lack coordination between federal states (*Steinmetz, et al. v. Germany* 2022).[27]

The role of federal German states in establishing climate laws and mitigation targets was challenged in a series of 11 cases brought against the subnational governments in Germany in the Federal Constitutional Court of Germany (*1 BvR 1565/21, 1 BvR 1566/21, 1 BvR 1669/21, 1 BvR 1936/21, 1 BvR 2574/21, 1 BvR 2575/21, 1 BvR 2054/21, 1 BvR 2055/21, 1 BvR 2056/21, 1 BvR 2057/21, 1 BvR 2058/21* 2022).[28] These claims argued that codifying a legally binding reduction path is required at the subnational level, as states bear co-responsibility for protecting human rights, including safeguarding future generations, within their sphere of competence. In 2022, the court gave one joint decision for all 11 complaints, refusing to admit them for adjudication based on a lack of adequate prospects Federal Constitutional Court of Germany (2022b).[29] The court found that the German federal legislature, not the subnational legislatures, is subject to implementing a carbon emissions budget. Additional claims have been brought before state courts in Germany seeking more ambitious climate action (*Deutsche Umwelthilfe (DUH) v. Nordrhein-Westfalen (NRW)* 2020; *Deutsche Umwelthilfe (DUH) v. Bayern* 2021; *Marlene Lemme, et al. v. State of Bayern [Subsidiary Claim]* 2021; *Deutsche Umwelthilfe [DUH] v. Baden-Württemberg [BaWü]* 2021).[30]

26 *Neubauer, et al. v. Germany*, Federal Constitutional Court of Germany, 29 April 2021 (Germany).

27 *Steinmetz, et al. v. Germany*, Federal Constitutional Court of Germany, 24 January 2022 (Germany).

28 See Federal Constitutional Court, Germany: http://climatecasechart.com/non-us-jurisdiction/federal-constitutional-court/.

29 *1 BvR 1565/21, 1 BvR 1566/21, 1 BvR 1669/21, 1 BvR 1936/21, 1 BvR 2574/21, 1 BvR 2575/21, 1 BvR 2054/21, 1 BvR 2055/21, 1 BvR 2056/21, 1 BvR 2057/21, 1 BvR 2058/21*, Federal Constitutional Court of Germany, 18 January 2022 (Germany).

In 2021, the Brussels Court of First Instance held in *VZW Klimaatzaak v. Kingdom of Belgium & Others* (2021) that Belgium and three subnational governments had breached their duty of care under the Civil Code by failing to take necessary measures to prevent the harmful effects of climate change and comply with their mitigation targets. Further, the court found that by failing to take sufficient climate action to protect the life and privacy of the plaintiffs, the defendants were in breach of their obligations under articles 2 and 8 of ECHR. However, the court declined to set more stringent emissions reduction targets on separation of powers grounds. In November 2021, Klimaatzaak appealed the judgment pertaining to the court's refusal to set specific binding targets related to the reduction of GHG emissions over time.[31]

In a case involving similar claims decided in 2022, *Klimatická žaloba ČR v. Czech Republic* (2022), the Prague Municipal Court ordered the State to urgently take the necessary measures to address climate change and devise a precise plan to achieve the goals of the Paris Agreement.[32]

Several claims filed in other jurisdictions also challenge the adequacy of national climate action under ECHR provisions that have been integrated into domestic law. In *A Sud et al. v. Italy* (2021), an environmental NGO and more than 200 individuals filed a suit against the Italian Government for failing to take actions necessary to meet the Paris Agreement's temperature goal of well below 2°C with respect to pre-industrial levels while aiming to limit temperature increase to 1.5°C. They have sought a court order to reduce emissions by 92 per cent by 2030 compared with 1990 levels, based on Italy's "fair share" of global emissions under the Paris Agreement.[33] Similarly, in 2021 ClientEarth in Poland brought five identical suits on behalf of private citizens against the Polish Government, alleging that the Government has permitted GHG emissions from its territory in excess of the nation's "fair share" under the Paris Agreement, in violation of its human rights obligations (*ClientEarth v. Poland [on Behalf of M.G.]* 2021; *ClientEarth v. Poland [on Behalf of M.O.]; ClientEarth v. Poland [on Behalf of M.S.]; ClientEarth v. Poland [on Behalf of P.N.]; ClientEarth v. Poland [on Behalf of P.N.]* 2021).[34]

Cases that have challenged specific projects or policies based on human rights obligations under ECHR have had limited success to date. In *Greenpeace et al. v. Austria* (2020), the Austrian Constitutional Court dismissed a lawsuit requesting an invalidation of tax exemptions granted to air travel and not railways, finding that rail passengers do not have standing to sue over preferential tax treatment.[35] Similarly, in *Greenpeace Netherlands v. State of the Netherlands* (2020), The Hague District Court found that the State does not have a legally enforceable obligation under ECHR to attach climate conditions to a COVID-19 bailout package for the Dutch airline KLM Royal Dutch Airlines and deferred to the executive branch's discretion in responding to the pandemic.[36] In *Plan B Earth and Others v. The Secretary of State for Business, Energy, and Industrial Strategy* (2019), the High Court of Justice in London refused permission to proceed in a case alleging that the United Kingdom's continued support for high-emission transportation and fossil fuel industries within the

30 *Deutsche Umwelthilfe (DUH) v. Nordrhein-Westfalen (NRW)*, Higher Administrative Court of North Rhine-Westphalia, 3 December 2020 (Germany).
Deutsche Umwelthilfe (DUH) v. Bayern, Higher Administrative Court of Bayern, 24 June 2021 (Germany).
Marlene Lemme, et al. v. State of Bayern (Subsidiary Claim), Bayern Constitutional Court, 30 June 2021 (Germany).
Deutsche Umwelthilfe (DUH) v. Baden-Württemberg (BaWü), Higher Administrative Court of Justice Baden-Württemberg, 8 November 2021 (Germany).

31 *VZW Klimaatzaak v. Kingdom of Belgium & Others*, Brussels Court of First Instance, 17 November 2021 (Belgium).

32 *Klimatická žaloba ČR v. Czech Republic*, Municipal Court in Prague, Judgment No. 14A 101/2021, 15 June 2022 (Czech Republic).

33 *A Sud et al. v. Italy*, Civil Court of Rome, 5 June 2021 (Italy).

34 *ClientEarth v. Poland (on Behalf of M.G.)*, Białystok Court of Appeal, 8 September 2021 (Poland).
ClientEarth v. Poland (on Behalf of M.O.), District Court, 2021 (Poland).
ClientEarth v. Poland (on Behalf of M.S.), District Court, 2021 (Poland).
ClientEarth v. Poland (on Behalf of P.R.), District Court, Poland, 2021 (Poland).
ClientEarth v. Poland (on Behalf of P.N.), Poznań Regional Court, 20 December 2021 (Poland).

35 *Greenpeace et al. v. Austria*, Constitutional Court of Austria, Decision No. G 144-145/2020-13, V 332/2020-13, 30 September 2020 (Austria).

36 *Greenpeace Netherlands v. State of the Netherlands*, The Hague District Court, Decision No. ECLI:NL:RBDHA:2020:12440, 9 December 2020 (Netherlands).

United Kingdom and its overseas territories violates rights protected by ECHR and the United Kingdom's Human Rights Act.[37]

Rights-based litigation challenging national climate policies and policy- and project-level approvals has also emerged outside of Europe. In *ENVironnement JEUnesse v. Procureur General du Canada* (2022), an environmental non-profit organization alleged that Canada's GHG reduction targets were insufficient to avoid dangerous climate change impacts, that the plans to meet these targets were themselves inadequate, and that both of these breach Canada's obligations to protect the human rights of young people under the Canadian Charter of Rights and Freedoms and the Québec Charter of Rights and Freedoms. The federal Government submitted that the issues were not justiciable because they were inherently political and outside the competence of the court and because the allegation was government inaction. In December 2021, the Québec Court of Appeal accepted the Government's arguments and denied a motion to certify a class action by the group of citizens. The appellants filed an application for leave to appeal to the Supreme Court of Canada, but this application was denied.[38]

In *Laboratório do Observatório do Clima v. Minister of Environment and Brazil* (2022), a network of civil society organizations filed a class action in the judicial section of Amazonas against the Brazilian Government. The plaintiffs requested that the National Climate Change Policy be updated to align Brazil's GHG emissions with a 1.5ºC global warming scenario. The plaintiffs asserted that climate change affects a wide range of human rights such as the rights to life, dignity, health, food and housing, as wellas the constitutionally recognized right to a healthy environment.[39]

The violation of human rights has also been used as the basis for legal arguments demanding adaptation measures from a government. In *Tsama William and Others v. Uganda's Attorney General and Others* (2020), the victims of recurring landslides in Bududa District, Uganda, filed a suit against the Government for failing to implement landslide adaptation measures. The applicants requested a declaration of violation of rights, damages, and compensation for the loss of life, threats to life, destruction of property, infringement of their other fundamental human rights and the costs of resettlement to safer areas. The case is pending as at 31 December 2022.[40]

ii. The right to a healthy environment

Several cases have made challenges to national climate policy premised on the right to a healthy environment, as laid out in several domestic constitutions (Vilchez Moragues and Savaresi 2021).[41] The majority of these cases are found in the Global South.

In 2022, the Brazilian Supreme Court held in *PSB et al. v. Brazil (on Climate Fund)* (2022) that the Paris Agreement is a human rights treaty, which enjoys "supranational" status. This "supralegality" of human rights treaties means that they are above "regular" laws in the legal hierarchy. Accordingly, any Brazilian law or decree that contradicts the Paris Agreement, including the NDC, may be invalidated. The case concerned the Government's failure to adopt administrative measures concerning the allocation of funds of a financial mechanism for subsidizing mitigation and adaptation measures. The Supreme Court ruled that the executive branch has a constitutional duty to execute and allocate the funds to mitigate climate change, based on both the separation of powers and the constitutional right to a healthy environment. The court further found that the judiciary, in turn, must act to avoid the regression of environmental protection. The constitutional duty to allocate the funds effectively means that there is a duty to mitigate climate change considering the international commitments under the climate change framework.[42]

37 *Plan B Earth and Others v. The Secretary of State for Business, Energy, and Industrial Strategy*, High Court of Justice of England and Wales, Claim No. CO/16/2018, 25 January 2019 (United Kingdom of Great Britain and Northern Ireland).

38 *ENVironnement JEUnesse v. Procureur General du Canada*, Superior Court of Québec, 28 July 2022 (Canada).

39 *Laboratório do Observatório do Clima v. Minister of Environment and Brazil*, Seventh Federal Environmental and Agrarian Court of the Judiciary Section of Amazonas, Ação Civil Pública No. 1027282-96.2021.4.01.3200, 13 May 2022 (Brazil).

40 *Tsama William and Others v. Uganda's Attorney General and Others*, High Court of Uganda at Mbale, Miscellaneous Case No. 024 of 2020, 14 October 2020 (Uganda).

41 Decisions highlighted in previous reports that rely on the right to a healthy environment include:
Leghari v. Federation of Pakistan, Lahore High Court, W.P. No. 25501/201, Granted, 25 January 2018 (Pakistan).
Future Generations v. Ministry of the Environment and Others, Colombia Superior Tribunals, Radicación 11001 22 03 000 2018 00319 00, 5 April 2018 (Colombia).
In re Court on Its Own Motion v. State of Himachal Pradesh and others, National Green Tribunal, CWPIL No. 15 of 2010, 9 May 2019 (India).

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In Mexico, the Supreme Court in *Amparo En Revision 610/2019* (2020) invalidated a rule that would have allowed higher ethanol content in gasoline, concluding that the right to a healthy environment and the precautionary principle required the evaluation of the potential of increased GHG emissions and an analysis of the country's commitments under the Paris Agreement.[43] In *Greenpeace Mexico v. Ministry of Energy and Others (on the National Electric System Policies)* (2020), Mexico's First Circuit Collegiate Tribunal held that policies reducing the country's share of renewable energy violate the constitutional right to a healthy environment and are regressive.[44]

In *PSB et al. v. Brazil (on Deforestation and Human Rights)* (2022) seven political parties in Brazil brought an action against the federal Government for failing to implement the national deforestation policy, thereby contributing to dangerous climate change. The claims were based on fundamental constitutional rights, including the right to a healthy environment, the rights of Indigenous Peoples and the rights of present and future generations.[45] In *Institute of Amazonian Studies v. Brazil* (2022), as at April 2023, the plaintiffs are seeking recognition of a fundamental right to a stable climate for present and future generations under the Brazilian Constitution as well as an order to compel the federal Government to comply with the national climate law. The plaintiffs have alleged that the federal Government has failed to adhere to its action plans to prevent deforestation and mitigate and adapt to climate change.[46]

In *Greenpeace Nordic Ass'n v. Ministry of Petroleum and Energy (People v. Arctic Oil)* (2020), the claimants alleged that Norway's grant of deep-sea petroleum extraction licences within the South Barents Sea constituted a failure to exercise due diligence to protect against the human rights implications of climate change, contrary to the constitutional right to a healthy environment, and the rights to life and private and family life under the ECHR and the

42 *PSB et al. v. Brazil (on Climate Fund)*, Federal Supreme Court of Brazil, ADPF 708, 1 July 2022 (Brazil).

43 *Ruling on Modification to Ethanol Fuel Rule*, Supreme Court of Mexico, 610/2019, Opinion, 22 January 2020 (Mexico).

44 *Greenpeace Mexico v. Ministry of Energy and Others (on the National Electric System Policies)*, District Court in Administrative Matters, Amparo No. 104/2020, 17 November 2020 (Mexico).

45 *PSB et al. v. Brazil (on Deforestation and Human Rights)*, Federal Supreme Court of Brazil, ADPF 760, 6 April 2022 (Brazil).

46 *Institute of Amazonian Studies v. Brazil*, Federal Regional Court, Fourth Region, ACP No. 5048951-39.2020.4.04.7000, 29 March 2022 (Brazil).

Norwegian Constitution. On appeal, the Supreme Court of Norway held that future emissions from exported oil are too uncertain to bar the granting of licences for deep-sea extraction and that the constitutional right to a healthy environment does not grant individual rights to challenge petroleum-related activities (Voigt 2021). Notwithstanding, the court recognized the constitutional right of private parties to be informed of petroleum-related decisions that could have a local environmental impact (Gociu and Roy 2021). The plaintiffs have appealed this case to ECtHR (see Part 3.B.ii.c).[47]

Box 5: Children and youth-led claims and future generations

As at 31 December 2022, about 34 cases have been brought by and on behalf of children and youth (usually defined as people younger than 25 years old) based on human rights, as tracked in the Sabin Center's databases. These cases rely on children and youth's special vulnerability to climate harm and on the principle of intergenerational equity. Children and youth plaintiffs argue that due to their young age, they will endure the effects of climate change – which will intensify over time – for longer. Two claims were led by girls as young as 7 and 9 years old, respectively. In *Rabab Ali v. Federation of Pakistan & Another* (2016), the 7-year-old girl challenged Pakistan's climate policies from a rights-based perspective.[48] In *Ridhima Pandey v. Union of India & Ors*. (2017), a 9-year-old girl questioned the adequacy of India's climate mitigation efforts based on the public trust doctrine.[49] The disproportionate effects of climate change give rise to claims for equal treatment (Gradoni and Mantovani 2022). The United Nations Committee on the Rights of the Child recognized the merits of this type of claim by stating that children "are particularly affected by climate change, both in terms of how they experience its effects and the potential of climate change to affect them throughout their lifetimes, particularly if immediate action is not taken" (Sacchi *et al.* 2021). Cases generally focus on (i) insufficient efforts to reduce carbon emissions and meet climate commitments, (ii) insufficient efforts to implement mitigation and adaptation measures and (iii) specific regulatory approvals that are expected to have dramatic climate impacts (Parker *et al.* 2022).

Several children and youth-led cases have been filed in the United States of America. These cases have mostly relied on the public trust doctrine and/or constitutional rights. Two cases, *Juliana v. United States* (*Juliana*) (2020) and *Held v. State* (2020), are still pending determination by the court. The plaintiffs in Juliana – a case that was analysed in the 2020 Litigation Report[50] – are currently seeking permission to amend their complaint, which was dismissed in a decision from the Court of Appeals for the Ninth Circuit.[51] The plaintiffs and defendants in *Held v. State* are moving to trial in Montana state court.[52] The vast majority of cases (14) have not been successful on the merits and were dismissed for a lack of justiciability, standing, or on the court's decision to defer to the executive and legislative branches (Sabin Center for Climate Change Law 2023).

47 *Greenpeace Nordic Ass'n v. Ministry of Petroleum and Energy (People v. Arctic Oil),* Supreme Court of Norway, HR-2020-2472-P, Case No. 20-051052SIV-HRET, 23 January 2020 (Norway).

48 *Rabab Ali v. Federation of Pakistan & Another,* Supreme Court of Pakistan, Constitution Petition No. I of 2016, April 2016 (Pakistan).

49 *Ridhima Pandey v. Union of India & Ors*., National Green Tribunal, Original Application No. 187/2017, March 2017 (India).

50 This was a case in which young plaintiffs claimed that their constitutional rights to life, liberty, and property were violated by policies allowing fossil fuel production, consumption and combustion at "dangerous levels". See the 2020 Litigation Report, pages 15, 39, 43 and 44.

51 *Juliana v. United States*, United States Court of Appeals for the Ninth Circuit, 947 F.3d 1159, Granted, 17 January 2020 (United States of America).

52 *Held v. State*, Montana District Court, No. CDV-2020-307, Complaint, March 13 2020 (United States of America).

Cases have also been filed in Australia, Brazil, Canada, Colombia, Germany, Guyana, India, Ireland, Italy, Mexico, Netherlands, New Zealand, Norway, Pakistan, the Philippines, Poland, the Republic of Korea, South Africa, Spain, Uganda and the United Kingdom, as well as in CJEU, ECtHR and IACHR (Parker *et al.* 2022).[53]

Box 6: Climate litigation cases brought by women

Certain groups' vulnerability to the pervasive impacts of climate change is slowly being addressed in climate litigation. While a number of cases have addressed the impacts of climate change on children and future generations, as noted above, and on Indigenous groups as noted in the future trends section (Part 4), other groups have started using arguments related to equality before the law to request certain protective measures from their respective governments. For example, four cases in Chile, Pakistan, Switzerland and ECtHR were brought by girls or women who claimed they were disproportionally affected by climate change. In two cases, these arguments were unsuccessful. For example, in KlimaSeniorinnen v. Switzerland (2020) (see Part 1.A.ii.c), the Swiss Federal Administrative Court found that women older than 75 years were not exclusively affected by climate change. *Women from Huasco and Others v. the Government of Chile, Ministry of Energy, Environment and Health* (2022) was dismissed on procedural grounds.[54] A recent study has assessed how gender-based arguments have been used in climate litigation in Latin America, finding that plaintiffs and courts have failed to fully engage with a gender analysis to understand the disproportionate impacts suffered by marginalized groups in the region (Urzola forthcoming). Two cases are still pending. KlimaSeniorinnen (2022) (now at ECtHR) raises arguments on the disproportionate impact of climate change on senior women to ECtHR.[55] In *Maria Khan et al. v. Federation of Pakistan et al.* (2019), a coalition of women have argued that since climate change has a disproportionate impact on women, the federal Government's climate inaction violates women's rights to equal protection under the law and no discrimination on the basis of sex.[56]

53 Two cases had positive outcomes on the merits: *Future Generations v. Ministry of the Environment and Others* (2018) and *Neubauer, et al. v. Germany* (2021). One case had a negative outcome on the merits: *Greenpeace Nordic and Others v. Norway* (2021).
Cases that were dismissed for lack of justiciability and/or standing include: *PUSH Sweden, Nature and Youth Sweden and Others v. Government of Sweden* (2016), *Ridhima Pandey v. Union of India & Ors* (2018), *La Rose v. Her Majesty the Queen* (2019), *Six Youths v. Minister of Environment and Others* (2021), *Sacchi, et al. v. Argentina, et al. (2021),* and *ENvironnement JEUnesse v. Procureur General du Canada* (2022).
Depending on the jurisdiction, the outcome of a case on separation of powers grounds may be a merits decision or a justiciability question. Several cases are expected to proceed on the merits: *Rabab Ali v. Federation of Pakistan & Another* (2016), *Álvarez et al. v. Peru* (2019), *Do-Hyun Kim et al. v. South Korea* (2020), Youth Verdict v. Waratah Coal (2020), *Mathur et al. v. Her Majesty the Queen in Right of Ontario* (2020), *Duarte Agostinho and Others v. Portugal and 32 Other States* (2021), and *Youth v. Government of Mexico* (2022).

54 *Women from Huasco and Others v. the Government of Chile, Ministry of Energy, Environment and Health*, Court of Appeal of Copiapo, No. 323-2021, 7 May 2022 (Chile).

55 *KlimaSeniorinnen v. Switzerland*, ECtHR, Application No. 53600/20, 5 December 2022 (European Court of Human Rights).

56 *Maria Khan et al. v. Federation of Pakistan et al.*, Lahore High Court, No. 8960, Filed, 15 February 2019 (Pakistan).

II. Domestic enforcement of international climate change commitments

National and subnational governments commit to addressing climate change through varied international agreements and related national legislation or policy statements. These commitments may be subject to litigation challenging their scope, mode of implementation or non-execution. Governments are the most common defendants in litigation challenging mitigation and adaptation commitments, but as indicated in the 2020 Litigation Report, similar suits have been brought against corporations and other institutions. As more governments and companies commit to net-zero targets, more litigation that questions the implementation of these plans will likely emerge.

> **"Governments are the most common defendants in litigation challenging mitigation and adaptation commitments, but as indicated in the 2020 Litigation Report, similar suits have been brought against corporations and other institutions."**

Several cases in Europe have questioned governments' compliance with and implementation of their national mitigation commitments or net-zero strategies. Two French decisions from 2021 have specifically assessed the French Government's compliance with its commitments. In *Notre Affaire à Tous and Others v. France* (2021) (part of L'Affaire du siècle), the Administrative Court of Paris held that the State's climate inaction and failure to meet its carbon budget goals have caused climate-related ecological damages under international and European climate directives and regulations, the French Environmental Charter, Energy Code and Civil Code.[57] The court later ordered the State to take immediate and concrete actions by 31 December 2022 to comply with its mitigation commitments under national laws and repair the climate-related ecological damages caused by inaction, including subtracting excess emissions in the subsequent year. Any future slippage of emissions beyond the legislative commitments was also to be compensated by the French Government. In *Commune de Grande-Synthe v. France* (2021), the Council of State of France found that the Government had failed to adopt the necessary legislative measures to comply with its mitigation commitments. The refusal to take further action was incompatible with France's obligations under French and European Union law. The Council of State ordered the Government to "take all the measures necessary" to meet its climate goals by bending the curve of GHG emissions, including a 40 per cent reduction by 2030. The procedure concerning the evaluation of the Government's compliance with the decision is currently ongoing.

In the United Kingdom, a case was brought challenging the Government's Net Zero Strategy. In *R (oao Friends of the Earth) v. Secretary of State for Business Energy and Industrial Strategy* (2022), Friends of the Earth asked for judicial review of the economy-wide decarbonization strategy and the heat and buildings strategy for decarbonizing heating and homes. Friends of the Earth claimed that the policies will not enable compliance with the carbon budgets set under the Climate Change Act and that the strategy does not assess its impacts on people with protected characteristics, such as people with disabilities, people of colour and older people as required under the Equality Act. In July 2022, the High Court of Justice found that the United Kingdom Government had failed to comply with its legal duties under the Climate Change Act 2008 when approving the Net Zero Strategy.[58] That failure rested not on the strategy's content, but on the absence of key evidence, assumptions and numbers that the secretary of state should have relied on when approving the strategy but were missing from the final document.

57 *Notre Affaire à Tous and Others v. France* (2021), Administrative Court of Paris, Nos. 1904967, 1904972, 1904976/4-1, 21 October (France)

58 *R (oao Friends of the Earth) v. Secretary of State for Business Energy and Industrial Strategy,* High Court of Justice of England and Wales, EWHC 1841, 18 July 2022 (United Kingdom of Great Britain and Northern Ireland).

In Latin America, several climate litigation cases were brought challenging government efforts to relax climate regulation or deregulate. This trend, which was highlighted in the 2020 report, continues in countries like Brazil and Mexico. Cases in Brazil include *Institute of Amazonian Studies v. Brazil* (2022) and *PSB et al. v. Brazil (on Deforestation and Human Rights)* (2022). Cases in Mexico include *Greenpeace Mexico v. Ministry of Energy and Others (on the Energy Sector Program)* (2021), where Greenpeace has argued that the Energy Sector Program violates the right to a healthy environment and the right to access electricity based on renewable sources by promoting fossil fuel use at the expense of investments in renewable energy, GHG emissions reduction and adaptation.[59] Cases in Mexico include *Greenpeace Mexico v. Ministry of Energy and Others (on the National Electric System Policies)* (2020), where Greenpeace questioned the constitutionality of electricity sector policies that would limit renewable energy. In the latter case, the First Circuit Collegiate Tribunal held that the policies in question were regressive and unconstitutional as they violated the right to a healthy environment and the international climate framework, displaced renewable energies and effectively prevented Mexico from meeting GHG emission reduction targets. Three separate lawsuits from 2021 (brought by civil society organizations, youth groups, individual young people and members of the Mexican Senate Minority) further challenged amendments to Mexico's Electric Industry Law, which favoured coal and oil-fired power plants (*Nuestros Derechos al Futuro y Medio Ambiente Sano et al., v. Mexico [Unconstitutionality of the reform to the Electric Industry Law]* 2022; Challenge to the Constitutionality of Amendments to the Rules Governing Clean Energy Certificates 2022; *Julia Habana et al., v. Mexico [Unconstitutionality of the reform to the Electricity Industry Law]* 2022).[60] These cases cite the Mexican Constitution's right to a healthy environment, the Paris Agreement and sustainability principles in the Electric Industry Law. The cases are still pending as at 31 December 2022.

In 2022, the Supreme Court of the United States of America issued a decision in *West Virginia v. EPA* (2022), and held that section 111(d) of the Clean Air Act did not give the United States Environmental Protection Agency (EPA) the authority to use "generation-shifting" measures to set CO_2 emission limits for power plants. In doing so, the court reversed a January 2021 decision by the Court of Appeals for the District of Columbia (D.C.) Circuit that found that the former President Trump Administration's repeal and replacement of the previous President Obama Administration's Clean Power Plan was based on a too-narrow construal of EPA's authority under section 111(d). The Clean Power Plan used generation-shifting measures as two of the three "building blocks" for the "best system of emission reduction" for power plants under section 111(d). One building block shifted electricity production from coal-fired to natural gas-fired units, and another building block shifted generation to low- or zero-carbon sources such as wind and solar.[61] The decision in West Virginia has reduced the EPA's discretion in finding innovative ways to regulate GHG emissions from power plants.

59 *Mexico, Greenpeace Mexico v. Ministry of Energy and Others (on the Energy Sector Program),* District Court in Administrative Matters, Amparo No. 372/2020, 19 March 2021 (Mexico).

60 *Mexico, Nuestros Derechos al Futuro y Medio Ambiente Sano et al., v. Mexico (Unconstitutionality of the reform to the Electric Industry Law),* District Court in Administrative Matters, Amparo No. 204/2021, 28 December 2022 (Mexico).
Challenge to the Constitutionality of Amendments to the Rules Governing Clean Energy Certificates, Supreme Court of Mexico, Acción de Inconstitucionalidad 64/2021, 7 April 2022 (Mexico).
Julia Habana et al., v. Mexico (Unconstitutionality of the reform to the Electricity Industry Law), Supreme Court of Mexico, Amparo No. 210/2021, 22 December 2022 (Mexico).

61 *West Virginia v. EPA,* Supreme Court of the United States, 142 S. Ct. 2587, 30 June 2022 (United States of America).

III. Keeping fossil fuels and carbon sinks in the ground

Cases that challenge specific resource-extraction and resource-dependent projects (as well as environmental permitting and review processes to ensure adequate assessment of the projects' climate change implications) represent another highly visible category of climate cases. These cases relate to the long-term, global effect of projects extracting or processing fossil fuels as well as to the local impacts of mining and drilling activities on water, land use, air quality and biodiversity. These cases are increasingly alleging that proper consideration of a project's impacts should include the extent to which the project facilitates fossil fuel consumption elsewhere in the world and for an extended period into the future. The 2017 and 2020 Litigation Reports described key cases in Chile, Colombia, Estonia, Japan, Kenya, Norway, Pakistan, the United Kingdom and United States of America. Several of those cases are still pending as at 31 December 2022. Additional cases seeking to keep fossil fuels in the ground have targeted various sectors, including fossil fuel and mining extraction, power plants, roads, other types of fossil fuel infrastructure, land use and carbon sinks. This section highlights cases that question (i) a project's consistency with the Paris Agreement or a government's net-zero commitments and (ii) EIA requirements.

A. Consistency with the Paris Agreement or net-zero commitments

A number of cases have been brought challenging government approvals based on a project's inconsistency with the Paris Agreement or a country's net-zero commitments.

The Court of Appeal (Civil Division) of England and Wales in *ClientEarth v. Secretary of State* (2021) declined to address whether the conversion of a power plant from coal to natural gas ignored the United Kingdom's net-zero target, finding that GHG emissions were not a "freestanding reason for refusal" of a project's approval. The court reasoned that the relevant agency had discretion over the weight to assign to GHG emissions and that the secretary of state properly balanced the project's adverse effects, including GHG emissions, with the positive effects, including socioeconomic outcomes and the reuse of existing infrastructure.[62]

In New Zealand, several students have sued the New Zealand Minister of Energy and Resources, challenging the decision to grant permits for onshore oil and gas exploration as inconsistent with the Government's legal obligations under the country's Climate Change Response (Zero Carbon) Amendment Act 2019 (*Students for Climate Solutions Inc v. Minister of Energy and Resources* 2022).[63]

In *Citizens' Committee on the Kobe Coal-Fired Power Plant v. Japan* (2023), the Osaka District Court rejected a request for an injunction to prevent the construction and operation of two new units at a coal-fired plant in Japan. The petitioners argued that the project was inconsistent with Japan's 2030 and 2050 climate targets. The court found that the plaintiffs' human rights claims were general rather than individual and therefore lacked standing. The court further deferred to the discretion of the granting authority.[64] A similar lawsuit, also currently pending, was filed by the same NGO against the two private companies planning the project (*Citizens' Committee on the Kobe Coal-Fired Power Plant v. Kobe Steel Ltd., et al.* 2023).[65]

The Paris Agreement calls for parties to respect, promote and consider their obligations on human rights including aspects of gender equality, intergenerational equity and the empowerment of women. In *Women from Huasco and Others v. the Government of Chile, Ministry of Energy, Environment and Health* (2022), a group of women called for the shutdown of two thermoelectric power plants,

62 *ClientEarth v. Secretary of State*, Court of Appeal (Civil Division) of England and Wales, Case No. C1/2020/0998/QBACF, 21 January 2021 (United Kingdom of Great Britain and Northern Ireland).

63 *Students for Climate Solutions Inc v. Minister of Energy and Resources*, High Court of New Zealand, NZHC 2116 Decided, 24 August 2022 (New Zealand).

64 *Citizens' Committee on the Kobe Coal-Fired Power Plant v. Japan*, Supreme Court of Japan, 9 March 2023 (Japan).

65 *Citizens' Committee on the Kobe Coal-Fired Power Plant v. Kobe Steel Ltd., et al.*, Kobe District Court, 20 March 2023 (Japan).

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arguing they were contrary to Chile's decarbonization plans, the Paris Agreement and their human rights. In May 2022, the Court of Appeals of Copiapo rejected the claim on the grounds of separation of powers. The case was appealed to the Chilean Supreme Court.

Similar claims have been brought in Australia. In *Sharma and others v. Minister for the Environment* (2022), youth plaintiffs filed a lawsuit against the Australian Federal Minister for the Environment, arguing that the Minister owed a common-law duty of care to Australian children to avoid causing climate harm in exercising her statutory powers to approve a coal mine expansion. In July 2021, the Federal Court of Australia declared that the Minister had a duty to take reasonable care in the exercise of her powers under the Environment Protection and Biodiversity Conservation Act 1999 to avoid causing personal injury or death to Australian children "arising from emissions of CO_2 into the Earth's atmosphere".[66] In March 2022, the Full Federal Court of Australia, an intermediate appellate court, unanimously overturned that decision (Tigre 2022b). The court found that the relationship between the youth plaintiffs and the Minister lacked the closeness and directness that the common law demands before finding a duty is owed by one party to another. The court also rejected the Minister's argument that the primary judge made

66 *Mullaley Gas and Pipeline Accord Inc v. Santos NSW (Eastern) Pty Ltd.*, New South Wales Land and Environment Court, NSWLEC 147, 16 December 2021 (Australia).

findings based on unfounded evidence of climate change. The plaintiffs announced that they would not appeal the decision.

In *Mullaley Gas and Pipeline Accord Inc v. Santos NSW (Eastern) Pty Ltd* (2021), the Land and Environment Court New South Wales dismissed a challenge to the approval of a coal seam gas field and associated infrastructure. The court found that the plaintiffs had not sufficiently established that the planning commission erred in (i) considering the expected GHG emissions; (ii) excluding Scope 3 or downstream GHG emissions from its assessment; and (iii) failing to consider the climate impacts of gas transmission pipelines.[67] However, in *KEPCO Bylong Australia v. Independent Planning Commission and Bylong Valley Protection Alliance* (2021), the New South Wales Court of Appeal found that the Commission had adequately found that KEPCO had not proposed to minimize GHG emissions despite the State Climate Change Policy's requirements.[68] Similar pending claims question the validity of a water-sharing plan (*Nature Conservation Council of New South Wales v. Minister for Water, Property and Housing* 2022)[69] and power station licences (*Environment Victoria v. the EPA et al.* 2021).[70]

In *Guyane Nature Environnement and France Nature Environnement v. France* (2022), the Council of State ruled that a renewal of authorization of a thermal power plant in French Guiana – an overseas territory of France – did not need to consider France's overall mitigation goals. However, in April 2022, the administrative court cancelled the environmental authorization of the power plant given that there was an insufficient search for an alternative location and would pose a nuisance to protected species.[71] In New Zealand, the Government abandoned a project to fund and build a road after a judicial review claim questioned its compatibility with the Paris Agreement (*All Aboard Aotearoa v. Waka Kotahi* 2021).[72] Several similar cases, in which government permits and authorizations are challenged on climate grounds, are still pending as at 31 December 2022.


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67 *Mullaley Gas and Pipeline Accord Inc v. Santos NSW (Eastern) Pty Ltd.*, New South Wales Land and Environment Court, NSWLEC 147, 16 December 2021 (Australia).

68 *KEPCO Bylong Australia v. Independent Planning Commission and Bylong Valley Protection Alliance*, Court of Appeal of Australia, NSWCA 216, 14 September 2021 (Australia).

69 *Nature Conservation Council of New South Wales v. Minister for Water*, Property and Housing, New South Wales Land and Environment Court, Case 2021/00282599, 8 June 2022 (Australia).

70 *Environment Victoria v. the Environmental Protection Agency et al.* (2021), Supreme Court of Victoria, S ECI 2021 03415, 16 September 2021 (Australia).

71 *Guyane Nature Environnement and France Nature Environnement v. France*, Council of State of France, No. 455465, 456314, 455497, 455500, 10 February 2022 (France).

72 *All Aboard Aotearoa v. Waka Kotahi*, High Court of New Zealand, 4 June 2021 (New Zealand).

Three related cases, now combined, were filed in Argentina questioning the Ministry of Environment and Sustainable Development's decision to approve the implementation of an offshore seismic acquisition project.[73] In *Africa Climate Alliance et al. v. Minister of Mineral Resources & Energy et al. (#CancelCoal case)* (2022), NGOs launched a youth-led constitutional challenge questioning the South African Government's plans to procure new coal-fired power electricity.[74] In Denmark, an NGO questioned the construction of an artificial peninsula – a project developed as a climate adaptation measure – as it failed to account for GHG emissions as well as Danish and European Union net-zero targets (*The Climate Movement v. Ministry of Transportation* 2021).[75]

Cases have also been brought with the goal of protecting key ecosystems that act as carbon sinks. For example, in *Asociación Civil por la Justicia Ambiental v. Province of Entre Ríos et al.* (Delta del Paraná case) (2021), NGOs and a group of children have questioned three Argentinian provinces and a municipality's duty to protect the Delta del Paraná, a wetland of international importance under the Ramsar Convention on Wetlands of International Importance, that burned significantly throughout 2020. Relying on human rights and Argentina's obligation under the Paris Agreement, the plaintiffs asked the court to declare the rights of nature of the ecosystem due to its climate mitigation and adaptation characteristics.[76] A similar case was brought in Türkiye, related to the Marmara Lake, a wetland of national importance and a significant carbon sink. The plaintiffs argue that the government has failed to protect the lake, directly violating the Paris Agreement (*S.S. Gölmarmara ve Çevresi Su Ürünleri Kooperatifi v. Republic of Türkiye Ministry of Agriculture and Forestry* 2022).[77] Several Brazilian cases related to the protection of the Amazon rainforest also argue that the forest acts as a significant carbon sink (*Ministério Público Federal v. IBAMA* 2020; *Institute of Amazonian Studies v. Brazil* 2022; *PSB et al. v. Brazil [on Deforestation and Human Rights]* 2022; *PSB et al. v. Brazil [on Amazon Fund]* 2022).[78]

B. Environmental impact assessment requirements

Many cases in this category are partially or entirely premised on EIA and similar planning requirements. These cases often, though not always, challenge project permitting and approval decisions for failing to consider climate impacts as part of required environmental reviews.

In *Saonu and Morobe Provincial Government v. Minister for Environment and Conservation and Climate Change and Others* (2021), the Morobe Provincial Government in Papua New Guinea challenged the environmental permit of a mining lease for failing to consider climate change when issuing the permit, improper review of climate issues, inadequate consultation of affected communities and the irreparable environmental damages. In 2021, the Court of Justice at Waigani, Papua New Guinea, noted that the parties did not provide any information on whether the EIA factored levels of CO_2 emissions and impacts on the local and global environment or proposed measures to minimize such emissions. The court issued an order of stay pending substantial review.[79] Similarly, the Chilean Supreme Court ruled

73 See Federal Court of Mar del Plata N. 2, Argentina: http://climatecasechart.com/non-us-jurisdiction/federal-court-of-mar-del-plata-n-2/.

74 *Africa Climate Alliance et al., v. Minister of Mineral Resources & Energy et al. (#CancelCoal case)*, High Court of South Africa, Case No. 56907/21, 20 January 2022 (South Africa).

75 *The Climate Movement v. Ministry of Transportation*, Western High Court of Denmark, 22 October 2021 (Denmark).

76 *Asociación Civil por la Justicia Ambiental v. Province of Entre Ríos, et al.* (Delta del Paraná case), Supreme Court of Argentina, CSJ 542/2020, 28 December 2021 (Argentina).

77 *S.S. Gölmarmara ve Çevresi Su Ürünleri Kooperatifi v. Republic of Türkiye Ministry of Agriculture and Forestry*, Administrative Court of Manisa, July 2022 (Türkiye).

78 *Ministério Público Federal v. IBAMA*, Seventh Federal Environmental and Agrarian Court of the Judiciary Section of Amazonas, ACP No. 1007104-63.2020.4.01.3200, 21 May 2020 (Brazil).
PSB et al. v. Brazil (on Amazon Fund), Federal Supreme Court of Brazil, ADO 59/DF, 3 November 2022 (Brazil).

79 *Ministério Público Federal v. IBAMA*, Seventh Federal Environmental and Agrarian Court of the Judiciary Section of Amazonas, ACP No. 1007104-63.2020.4.01.3200, 21 May 2020 (Brazil).

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in 2022 in *Mejillones Tourist Service Association and others with the Environmental Evaluation Service (SEA) of Antofagasta* (2022) that climate impacts should be included in the environmental review process, including in a revision of older environmental permits.[80]

In South Africa, NGOs sought an interdict prohibiting seismic surveys off the coast of South Africa. The High Court ruled in *Sustaining the Wild Coast NPC and Others v. Minister of Mineral Resources and Energy and Others* (2022) that the exploration right was awarded without proper consultation or an assessment of climate impacts. The court recognized the risk of irreparable and imminent climate harm, as well as impacts on the communities' cultural practices and ocean conservation.[81]

Cases in the United States of America have also confirmed that consideration of climate change is a required component of EIAs. The D.C. Circuit Court of Appeals invalidated the Bureau of Ocean Energy Management's lease sale of offshore land in the Gulf of Mexico for oil and gas development in *Friends of the Earth v. Haaland* (2023), holding that the EIA was deficient because the Bureau did not consider changes in foreign oil consumption when evaluating GHG emissions associated with the lease sale.[82] The Ninth Circuit Court of Appeals found an EIA deficient for similar reasons in *Center for Biological Diversity v. Bernhardt* (2020).[83] In *Food & Water Watch v. FERC* (2022), the D.C. Circuit affirmed again in 2022 that the Federal Energy Regulatory Commission was required to consider the GHG emissions attributable to burning the gas to be carried by a pipeline in its EIA, at least in some circumstances.[84]

In *R (Finch on behalf of the Weald Action Group & Others) v. Surrey County Council (& Others)* (2022), claimants challenged permits issued for new hydrocarbon wells due to inconsistency with the United Kingdom's net-zero target and the Government's failure to consider Scope 3 or downstream emissions. The High Court initially dismissed the claim in 2020, finding that the Government failed to assess downstream emissions. On appeal, the Court of Appeal in 2022 issued a split decision in which the majority deferred to the Government's discretion and the dissent argued that the Government had failed to meet its EIA obligations.[85]

80 *Mejillones Tourist Service Association and others with the Environmental Evaluation Service (SEA) of Antofagasta*, Supreme Court of Chile, Case No. 6930-20216930-2021, 19 April 2022 (Chile).

81 *Sustaining the Wild Coast NPC and Others v. Minister of Mineral Resources and Energy and Others*, High Court of South Africa, Case No. 3491/2021, 1 September 2022 (South Africa).

82 *Friends of the Earth v. Haaland*, Court of Appeals for the D.C. Circuit, Nos. 22-5036, 22-5037, 22-5067, 24 January 2023 (United States of America).

83 *Center for Biological Diversity v. Bernhardt*, Ninth Circuit Court of Appeals, 982 F.3d 723, 7 December 2020 (United States of America).

84 *Food & Water Watch v. FERC*, Court of Appeals for the D.C. Circuit, 28 F.4th 277, 11 March 2022 (United States of America).

85 *R (Finch on behalf of the Weald Action Group & Others) v. Surrey County Council (& Others)*, Court of Appeal (Civil Division) of England and Wales, CO/4441/2019 and C1/2021/0261, 2022 (United Kingdom of Great Britain and Northern Ireland).

Several similar claims are still pending as at 31 December 2022. In *South Durban Community Environmental Alliance v. Minister of Environment and Others* (2021), an NGO challenged the South African Government's approval of offshore oil and gas exploration on the basis that it failed to consider climate impacts in the EIA.[86] In *South Durban Community Environmental Alliance & Groundwork v. Minister of Forestry, Fisheries, and the Environment* (2021), NGOs have challenged the authorization of a gas-fired power plant for inadequate assessment of climate impacts.[87] In *Thomas & de Freitas v. Guyana* (2021), two citizens alleged that Guyana violated constitutional rights by approving oil exploration licences to an ExxonMobil-led group.[88] In *Henry v. Environmental Protection Agency* (2022), three citizens questioned the decision of EPA of Guyana to grant a modified environmental permit allowing Esso/ExxonMobil to flare gas without considering GHG emissions.[89]

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86 *South Durban Community Environmental Alliance v. Minister of Environment and Others*, High Court of South Africa, June 2021 (South Africa).

87 *South Durban Community Environmental Alliance & Groundwork v. Minister of Forestry, Fisheries, and the Environment*, High Court of South Africa, 8 April 2021 (South Africa).

88 *Thomas & De Freitas v. Guyana*, Supreme Court of Guyana, 27 September 2021 (Guyana).

89 *Henry v. Environmental Protection Agency*, Supreme Court of Guyana, 2021-HC-DEM-CIV-FDA, 21 January 2022 (Guyana).

IV. Corporate liability and responsibility

From 2020 to 2022, a growing number of cases have emerged that name private parties as defendants and demonstrate an increasing diversity of legal strategies that use a variety of theories. Key examples include cases seeking to hold GHG emitters or fossil fuel companies responsible for climate harm, as well as cases against financial institutions on the basis that they have ignored or misused knowledge about climate change risk. The 2017 Litigation Report described several legal actions of this kind. It noted that plaintiffs had yet to establish that certain emitters were the proximate cause of the plaintiff's specific injuries. The 2020 Litigation Report highlighted several pending cases in the United States of America against fossil fuel producers seeking to hold corporations accountable for a share of climate change's impacts. These include claims that defendant companies are liable both for public nuisance due to their deceptive marketing of fossil fuels as well as their failure to warn the public and consumers about the foreseeable harm their products cause. While a company's liability for climate impacts has yet to be established, in at least one instance a fossil fuel company has been found to owe a duty to mitigate emissions from its products.

A. Corporate duty to mitigate emissions

Increasingly, climate litigation cases have targeted corporations in an attempt to identify their corporate responsibility to mitigate GHG emissions. The 2020 Litigation Report highlighted *Smith v. Fonterra Co-Operative Group Limited* (2022), a case brought against seven companies in the agriculture and energy sectors in New Zealand. As noted in the 2020 Litigation Report, the High Court of New Zealand ruled that the companies had no duty of care towards the plaintiffs as the climate damages were not reasonably foreseeable or proximately caused by the companies' actions. In an appeal, the Court of Appeal ruled that tort law was not the appropriate avenue for dealing with climate change, reasoning that every person in the world is at the same time the one responsible for causing the relevant harm and the victim of that harm. The case was granted leave to appeal to the New Zealand Supreme Court.[90]

The issue of a corporate duty of care was also recently analysed by a first instance court in the Netherlands. In *Milieudefensie et al.v. Royal Dutch Shell* (2022) (Milieudefensie), The Hague District Court ordered Dutch-based oil and gas multinational

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90 *Smith v. Fonterra Co-Operative Group Limited*, High Court of New Zealand, NZSC 35, 31 March 2022 (New Zealand). See also the 2020 Litigation Report pages 22, 38, 42, and 44.

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Royal Dutch Shell to reduce CO_2 emissions associated with its products by 45 per cent from 2019 levels by 2030. The judgment represents the first time a private company was ordered to comply with the Paris Agreement and was found to have a duty to mitigate GHG emissions under the Paris Agreement. The court grounded its decision in climate-related human rights responsibilities and tort-based duties, including those related to corporate due diligence, and on an unwritten standard of care based on the goals of the Paris Agreement and the United Nations Guiding Principles on Business and Human Rights.[91] The judgment is under appeal as at 31 December 2022.

France's 2017 Law on the Duty of Vigilance, which imposes parent-based due diligence obligations covering human rights and the environment, has also facilitated new climate claims against corporations. In *Notre Affaire à Tous and Others v. Total* (2021), plaintiffs have asked the court to order the oil and gas company Total to recognize the risks generated by its business activities and align its conduct with the Paris Agreement. After a debate on the court's competency to decide the case, the case will then move to the merits stage. In *Envol Vert et al. v. Casino* (2021), a coalition of NGOs sued the French supermarket chain Casino for its supply chain emissions related to the cattle industry in Brazil and Colombia. The case has challenged "emissions outsourcing" and targeted a company that has low emissions profiles in their corporate home but whose products have caused significant pollution in other jurisdictions. The case is still in the preliminary stage.[92]

91 *Milieudefensie et al. v. Royal Dutch Shell plc.*, The Hague District Court, C/09/571932 / HA ZA 19-379, 25 April 2022 (Netherlands).

92 *Envol Vert et al. v. Casino*, Judicial Court of Saint-Étienne, 2 March 2021 (France).

Box 7: Philippines Carbon Majors report

In 2022, the Commission on Human Rights of the Philippines published its National Inquiry on Climate Change, the outcome of its seven-year investigation into the responsibility of 47 fossil fuel-producing companies (the so-called "Carbon Majors") for climate change (Philippines, Commission on Human Rights of the Philippines 2022). The investigation was initiated in response to a petition by Greenpeace Southeast Asia and other environmental organizations and individual Filipino citizens in In re Greenpeace Southeast Asia and Others, who asked the Commission to investigate "the human rights implications of climate change and ocean acidification and the resulting rights violations in the Philippines," naming the Carbon Majors as respondents.

The Commission conducted a fact-finding mission that included hearings in Manila, London and New York. In its report, the Commission concluded that the Philippine Government owes a duty (based on the United Nations Guiding Principles on Business and Human Rights) to protect human rights and avoid abuses by non-State actors, and that the Government's refusal or failure to engage in meaningful and concrete action to mitigate climate change may be categorized as a human rights violation. The Commission further concluded that business enterprises must respect human rights, irrespective of whether domestic laws exist or are fully enforced domestically. This corporate duty includes the responsibility to avoid causing or contributing to adverse human rights impacts through harm to the environment or climate change. The Commission acknowledged that the Carbon Majors had early awareness, notice or knowledge of their products' adverse impacts on the environment and climate system and engaged in wilful obfuscation and obstruction to prevent meaningful climate action. The Commission concluded that the Carbon Majors have a corporate responsibility to undertake human rights due diligence and provide remediation.

Cases against corporations targeting a corporate duty to reduce GHG emissions were also brought in Germany after the decision in Neubauer. Three cases were filed against automakers seeking to compel them to strengthen their carbon emissions target and stop producing fossil fuel-emitting cars by 2030: *DUH v. BMW* (2021),[93] *DUH v. Mercedes-Benz* (2022),[94] and *Kaiser, et al., v. Volkswagen AG* (2021).[95] Grounding their case in the Paris Agreement and German federal climate law, the plaintiffs have argued that the automakers have been violating the fundamental right to climate protection (as recognized in Neubauer) and impinging on the rights and freedoms of future generations by not adhering to a fair carbon budget. In *Barbara Metz et al., v. Wintershall Dea AG* (2021), plaintiffs used similar legal grounds to seek an order to compel the energy company Wintershall Dea AG to strengthen its emissions target and give up the extraction of natural gas and crude oil by 2025.[96] All cases are in the preliminary stages as at 31 December 2022.

Two cases were recently filed in Italy before the OECD National Contact Point, seeking broader corporate emissions reductions. In *Rete Legalità per il Clima (Legality for Climate Network) v. Intense Livestock Farming Multinational Companies Operating in Italy* (2021), plaintiffs challenged the compatibility of the practice of intensive livestock farming with Italy's net-zero commitments.[97] In *Rete Legalità per il Clima (Legality for Climate Network) and others v. ENI* (2022), plaintiffs questioned the adequacy of the business plan pursued by the oil company ENI as it pertains to its commitment to net-zero emissions by 2050. Both cases are also in the preliminary stages.[98]

93 *Deutsche Umwelthilfe (DUH) v. Bayerische Motoren Werke AG (BMW)*, Regional Court of Munich, 3 September 2021 (Germany).

94 *Deutsche Umwelthilfe (DUH) v. Mercedes-Benz AG*, Regional Court of Stuttgart, 13 September 2022 (Germany).

95 *Kaiser, et al. v. Volkswagen AG*, Regional Court of Braunschweig, 11 November 2021 (Germany).

96 *Barbara Metz et al., v. Wintershall Dea AG*, Regional Court of Kassel, 4 October 2021 (Germany).

97 *Rete Legalità per il Clima (Legality for Climate Network) v. Intensive Livestock Farming Multinational Companies Operating in Italy*, OECD National Contact Point, 6 December 2021 (OECD).

98 *Rete Legalità per il Clima (Legality for Climate Network) and Others v. ENI*, OECD National Contact Point, 15 February 2022 (OECD).

Box 8: Nuisance cases in the United States of America

Nearly two dozen states and cities in the United States of America have sued large fossil fuel companies seeking compensation for damages related to climate change (*City of New York v. BP p.l.c.* 2021; *City of New York v. Exxon Mobil Corp* 2021; *Connecticut v. Exxon Mobil Corporation* 2022; *Vermont v. Exxon Mobil Corp* 2022; *City of Hoboken v. Exxon Mobil Corp* 2022; *City of Oakland v. BP p.l.c.* 2022; *Mayor & City Council of Baltimore v. BP p.l.c.* 2023; *City of Charleston v. Brabham Oil Co*. 2023; *City & County of Honolulu v. Sunoco LP* 2023; *Rhode Island v. Shell Oil Products Co.* 2023; *County of San Mateo v. Chevron Corp* 2023; *State v. American Petroleum Institute* 2023; *Delaware v. BP America Inc.*2023; *District of Columbia v. Exxon Mobil Corp* 2023; *Board of County Commissioners of Boulder County v. Suncor Energy [U.S.A.]* 2023).[99] The types of claims vary and include nuisance, negligence, strict liability and trespass claims, as well as claims under state and local consumer protection and unfair trade practices statutes. Since the first case was filed in 2017, litigation has centred on whether the cases belong in federal or state courts, raising the broader issue of the court's authority to address climate issues. Every court that has issued a decision to date has found that, because the cases seek to impose liability based on the companies' deceptive marketing, historic disinformation campaigns and failure to warn consumers and not the mere production of fossil fuels, the cases belong in state court (*City of Oakland v. BP p.l.c.* 2022; *Mayor & City Council of Baltimore v. BP p.l.c*. 2023; *City & County of Honolulu v. Sunoco LP* 2023; *Rhode Island v. Shell Oil Products Co.* 2023; *County of San Mateo v. Chevron Corp.* 2022; *Board of County Commissioners of Boulder County v. Suncor Energy (U.S.A.), Inc*. 2023).

At the time of this publication, there are several cases that are moving into litigation in state courts, including cases in Hawai'i, Maryland and Rhode Island, while others await final rulings on the issue. In *City of New York v. Chevron Corp.* (2019), the Second Circuit Court of Appeals (a federal court) affirmed the dismissal of New York City's case asserting common-law claims, which sought to impose liability based on the companies' fossil fuel production. The Second Circuit held that, as the case relates to federal common law, it displaced the state law claims. Furthermore, it held that the Clean Air Act (a federal statute) regulates any federal common-law claims related to domestic emissions. It also held that foreign policy concerns foreclosed federal common-law claims stemming from emissions outside the United States of America.[100] In contrast, a trial-level state court in Hawai'i denied defendants' motion to dismiss a lawsuit brought by the City and County of Honolulu. It distinguished the Second Circuit's decision, noting that the Hawai'i lawsuit sought to impose liability based on the companies' tortious speech and failure to warn, and not only the production of fossil fuels (*City & County of Honolulu v. Sunoco LP.* 2023).

99 *City of New York v. BP p.l.c., Court of Appeals for the Second Circuit*, No. 1:18-cv-00182, 24 April 2021 (United States of America).
City of New York v. Exxon Mobil Corp., District Court for the Southern District of New York, No. 1:21-cv-04807, 12 November 2021 (United States of America).
Connecticut v. Exxon Mobil Corporation, Court of Appeals for the Second Circuit, No. 21-1446, 31 August 2022 (United States of America).
Vermont v. Exxon Mobil Corp., District Court for the District of Vermont, No. 2:21-cv-260-wks, 2 September 2022 (United States of America).
City of Hoboken v. Exxon Mobil Corp., Court of Appeals for the Third Circuit, HUD-L-003179-20, 12 October 2022 (United States of America).
City of Oakland v. BP p.l.c., District Court for the Northern District of California, No. CGC-17-561370, 24 October 2022 (United States of America).
Mayor & City Council of Baltimore v. BP p.l.c., Supreme Court of the United States, No. 24-C-18-004219, 3 January 2023 (United States of America).
City of Charleston v. Brabham Oil Co., District Court for the District of South Carolina (Charleston Division), No. 2020CP1003975, 20 January 2023 (United States of America).
City & County of Honolulu v. Sunoco LP, Supreme Court of the United States, No. 1CCV-20-0000380, 22 February 2023 (United States of America).
Rhode Island v. Shell Oil Products Co., Supreme Court of the United States, No. PC-2018-4716, 22 February 2023 (United States of America).
County of San Mateo v. Chevron Corp., Supreme Court of the United States, No. 17CIV03222, 27 February 2023 (United States of America).
State v. American Petroleum Institute, Court of Appeals for the Eighth Circuit, No. 62-CV-20-3837, 23 March 2023 (United States of America).
Delaware v. BP America Inc., Supreme Court of the United States, No. N20C-09-097, 27 March 2023 (United States of America).
District of Columbia v. Exxon Mobil Corp., Court of Appeals for the D.C. Circuit, No. 2020 CA 002892 B, 31 March 2023 (United States of America).
Board of County Commissioners of Boulder County v. Suncor Energy (U.S.A.), Inc., Supreme Court of the United States, No. 2018CV030349, 5 April 2023 (United States of America).

100 *City of New York v. Chevron Corp.*, Court of Appeals for the Second Circuit, 993 F.3d 81, 1 April 2019 (United States of America).

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B. Corporate liability for adaptation

A limited number of cases have addressed the recognition of corporate liability for adaptation to climate change. Some pending lawsuits highlighted in the 2020 Litigation Report have yet to be decided as at 31 December 2022. These include *Luciano Lliuya v. RWE AG* (2022), a case brought by a Peruvian farmer against a German utility company seeking compensation for the costs of protecting the plaintiff's town from melting glaciers.[101] Due to delays related to the COVID-19 pandemic, the case remains in the evidentiary phase.

C. Responsibility of financial institutions

Courts are beginning to assess the responsibility of financial institutions for the climate dimensions of their investments. In *ClientEarth v. Belgian National Bank* (2022), plaintiffs argued that the bank had failed to meet environmental, climate and human rights requirements when purchasing bonds from fossil fuel and other GHG-intensive companies as part of the European Central Bank's Corporate Sector Purchase Programme (CSPP). ClientEarth argued that the CSPP undermines the European Union's emissions reduction targets and fails to take into account climate considerations and sought a preliminary reference to the CJEU to determine whether the decision to establish the CSPP was lawful.[102] Two cases in Brazil previously mentioned, *PSB et al. v. Brazil (on Climate Fund)* (2022) and *PSB et al. v. Brazil (on Amazon Fund)* (2022) have questioned the allocation of funds by the Brazilian National Development Bank (BNDES). In 2022, an NGO questioned how BNDES and its investment arm, BNDESPar, which are both publicly funded, have reported carbon emissions associated with BNDESPar's investment portfolio and maintained equity positions in sectors that are among the most carbon-intensive in the Brazilian economy (*Conectas Direitos Humanos v. BNDES and BNDESPar* 2022).[103] Finally, in *Kang et al. v. KSURE and KEXIM* (2022), a case from the Republic of Korea, plaintiffs have questioned the investment of an export credit agency in a gas reserve off the coast of Indigenous land in Australia.[104]

101 *Luciano Lliuya v. RWE AG*, Higher Regional Court of Essen, Case No. 2 O 285/15, On Appeal, May 2022 (Germany).

102 *ClientEarth v. Belgian National Bank*, Court of First Instance of Brussels, 21/38/C, Withdrawn, 2022 (Belgium).

103 *Conectas Direitos Humanos v. BNDES and BNDESPar*, Ninth Federal Civil Court of the Federal District, ACP 1038657-42.2022.4.01.3400, 22 June 2022 (Brazil).

104 *Kang et al. v. KSURE and KEXIM*, District Court of Seoul, 23 March 2022 (Republic of Korea).

V. Climate disclosures and greenwashing

Increased public awareness and understanding of climate change have spurred actions brought against corporations on claims of misrepresentative statements about climate change. This was well highlighted in the 2020 Litigation Report, which included a few examples of greenwashing cases in Australia, the United Kingdom and United States of America. All cases mentioned are pending as at 31 December 2022 (*York County v. Rambo* 2019; *People of the State of New York v. Exxon Mobil Corporation* 2020; *Ramirez v. Exxon Mobil Corp.* 2022; *Commonwealth v. Exxon Mobil Corp*. 2022; *O'Donnell v. Commonwealth* 2022),[105] and several others have been filed since. These kinds of actions involve plaintiffs bringing suits claiming they relied on those statements to make financial decisions, as well as cases brought by governments enforcing securities disclosures and consumer protection laws, and NGOs challenging alleged greenwashing or climate-washing campaigns. Investors continue to file suits alleging that public disclosures relating to climate risk were misleading or fraudulent, both in relation to the risk that a transition away from fossil fuels poses to their business or investment assets and the risk of physical impacts to infrastructure, operations and supply chains associated with climate change.

As observed in the 2020 Litigation Report, the climate disclosure cases are usually grounded in national consumer protection or corporate laws. Importantly, the regulatory context for climate disclosures is in flux. In 2019, the European Commission approved non-binding guidelines on reporting climate-related information (European Commission 2019). In 2021, it adopted the Corporate Sustainability Reporting Directive, a legislative proposal to strengthen the nature and extent of sustainability or Environmental, Social and Governance (ESG) reporting in the European Union, which would constitute substantial regulatory reform in the ESG reporting space (European Commission 2022). A new rule aimed at enhancing publicly traded companies' disclosure of climate-related risks has been proposed by the United States Securities and Exchange Commission (United States of America, Securities and Exchange Commission 2022). These regulations could lead to litigation on multiple fronts.

A. Protection of investors: climate disclosures

Cases concerning disclosure of investments in high-emitting GHG activities are found in Australia, Brazil and the European Union. In *ClientEarth v. European Investment Bank* (2021), the European Union General Court ordered the European Investment Bank to accept ClientEarth's petition for an internal review of the bank's decision to finance a biomass power plant. The request relied on the provisions of the United Nations Economic Commission for Europe Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention). ClientEarth claimed that the project overestimated the environmental advantages by underestimating the risks of logging and forest fire emissions.[106] In *Abrahams v. Commonwealth Bank of Australia* (2021), shareholders sued the Commonwealth Bank of Australia for disclosure of documents under the Corporations Act of 2001 of the bank's involvement in a series of fossil fuel projects that potentially infringed the bank's environmental

105 *York County v. Rambo*, District Court for the Northern District of California, No. 3:19-cv-00994, 22 February 2019 (United States of America).
People of the State of New York v. Exxon Mobil Corporation, Supreme Court of New York, No. 452044/2018, 27 February 2020 (United States of America).
Ramirez v. Exxon Mobil Corp., District Court for the Northern District of Texas, No. 3:16-cv-3111, 31 March 2022 (United States of America).
Commonwealth v. Exxon Mobil Corp., High Court of Massachusetts, No. SJC-13211, 24 May 2022 (United States of America).
O'Donnell v. Commonwealth, Federal Court of Australia, VID482/2020, 22 June 2022 (Australia).

106 *ClientEarth v. European Investment Bank*, CJEU, T-9/19 and C-212/21 P, Appealed, 2 February 2021 (European Union).

and social policies. The Federal Court allowed the plaintiffs to inspect a limited scope of documents and ordered the Commonwealth Bank of Australia to produce the relevant documents.[107] In *Clara Leonel Ramos and Bruno de Almeida de Lima v. State of São Paulo (Families for the Climate and IncentivAuto Program)* (2021), a community group in Brazil sued the state government of São Paulo seeking disclosure of the budgetary and climate impacts of the IncentivAuto Program, an over USD 150 million fund designed to incentivize automaking in the state. Plaintiffs alleged that the fund offered financing without requiring any climate mitigation efforts on the part of the carmakers. The plaintiffs claimed that the programme was potentially illegal for failing to minimize GHG emissions, in violation of São Paolo's Climate Change Plan.[108]

There have also been climate disclosure cases against pension funds brought in Australia, Luxembourg and the United Kingdom. The 2020 Litigation Report noted the Australian case *McVeigh v. Retail Employees Superannuation Trust* (2020), in which the plaintiff alleged that the fund violated the Corporations Act 2001 by inadequately responding to his request for information about the fund's knowledge of climate change risk, its assessment of that risk and the actions taken in response. The parties settled the case through an agreement for the fund to implement a net-zero goal; to measure, monitor and report climate progress in line with the Task Force on Climate-related Disclosures; to ensure investee climate disclosure; and to publicly disclose portfolio holdings, among other commitments.[109] In *Greenpeace A.S.B.L. v. Schneider* (2020), in which Greenpeace asked for information on how Luxembourg's sovereign fund aligned its investments with the goals of the Paris Agreement, the administrative judge ruled that the sovereign pension fund had to disclose the information sought. The court also found that the fund had no legal obligation to comply with the Paris Agreement.[110]

In *Ewan McGaughey et al., v. Universities Superannuation Scheme Limited* (2021), plaintiffs in the United Kingdom issued proceedings against the University Superannuation Scheme's directors under the directors' duty to act in the beneficiaries' best interests. Claimants argued that fossil fuels have been the worst-performing asset class since 2017 and that the failure to create a divestment plan has prejudiced the success of the company. The claimants further relied on the ECHR and the directors' duties under the Paris Agreement.[111]

In *Amis de la Terre and Sherpa v. Perenco* (2022), French NGOs attempted to obtain documents related to the environmental impacts of the oil company's operations in the Democratic Republic of the Congo. The Tribunal de Grande Instance de Paris and the Paris Court of Appeal denied their request, and so they appealed to the Court of Cassation. In March 2022, the Court of Cassation ruled in favour of the NGOs and held that any interested party may ask a French judge for an investigative measure if there is a legitimate reason to preserve or establish, before any proceedings, evidence that could be relevant to the resolution of a dispute, provided that the action envisaged is not manifestly inadmissible or contrary to the law or doomed to failure.[112]

In *In the Matter of AGL Limited* (2022), the plaintiff was a high-value shareholder of AGL Energy Limited, Australia's biggest GHG emitter. Although the plaintiff did not have access to the materials that AGL put to shareholders for a vote on a demerger, the plaintiff was concerned that those materials might not adequately address climate risks. Shareholders are typically unable to access the materials before the first hearing of the application. In May 2022, at a hearing of the Supreme Court of New South Wales, the plaintiff sought leave to be heard in the court's hearing of the application, including on the basis that the proposed demerger was not in the best interests of shareholders. Leave was granted, and AGL was

107 *Abrahams v. Commonwealth Bank of Australia*, Federal Court of Australia, NSD864/2021, 26 August 2021 (Australia).

108 *Clara Leonel Ramos and Bruno de Almeida de Lima vs. State of São Paulo (Families for the Climate and IncentivAuto Program)*, Court of Justice of São Paolo, No. 1047315-47.2020.8.26.0053, 10 June 2021 (Brazil).

109 *McVeigh v. Retail Employees Superannuation Trust*, Federal Court of Australia, NSD1333/2018, Settled, 2 November 2020 (Australia).

110 *Greenpeace A.S.B.L. v. Schneider*, Administrative Court of Luxembourg, No. 43604 du rôle, 12 March 2020 (Luxembourg).

111 *Ewan McGaughey et al. v. Universities Superannuation Scheme* Limited, High Court of Justice of England and Wales, EWHC 1233, 27 October 2021 (United Kingdom of Great Britain and Northern Ireland).

112 *Amis de la Terre and Sherpa v. Perenco*, Court of Paris, No. 20-22.444, 9 March 2022 (France).

required to provide the scheme materials to the plaintiff to review. The court ordered the unamended publication of the documents. AGL later decided to withdraw the demerger proposal.[113]

B. Protection of consumers: greenwashing complaints

Greenwashing complaints allege that corporate advertising contains false or misleading information about climate change impacts contrary to responsible advertising or fair competition legislation or standards.

In one case, the Italian Competition Authority has questioned Eni's Diesel+ advertising campaign as it pertained to the green claims in the advertising messages, which, according to the Competition Authority, have disseminated false and omissive information regarding the fuel's environmental impact and GHG emissions reductions (*Italian Competition Authority Ruling Eni's Diesel+ Advertising Campaign* 2019).[114] The United Kingdom's Advertising Standards Authority (ASA) found that airline Ryanair's claims of having low CO_2 emissions and being the lowest-emissions airline were misleading. The ASA found that consumers would find insufficient information in the advertisements to substantiate that they would reduce their personal CO_2 emissions compared with flying with another carrier (*ASA Ruling on Ryanair Ltd t/a Ryanair* 2020).[115] In another case, the ASA concluded that Shell had to clarify that the carbon offsetting was contingent on membership in a loyalty scheme. Shell's campaign on a scheme that allowed customers to "drive carbon-neutral" through offsetting emissions of fuel purchases was ruled misleading (*ASA Ruling on Shell UK Ltd.'s Shell Go+ Campaign* 2020).[116] New Zealand's energy company Firstgas' campaign on "zero-carbon gas" was also deemed misleading by the ASA Complaints Board due to

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113 *In the Matter of AGL Limited*, Court of New South Wales, Common Law Division, NSWSC 576, 12 May 2022 (Australia).

114 *Italian Competition Authority Ruling Eni's Diesel+ Advertising Campaign*, Regional Administrative Court of Lazio, 20 December 2019 (Italy).

115 *ASA Ruling on Ryanair Ltd t/a Ryanair Ltd*, Advertising Standards Authority, Complaint No. G19-1035778, 5 February 2020 (United Kingdom of Great Britain and Northern Ireland).

116 *ASA Ruling on Shell UK Ltd.'s Shell Go+ Campaign*, Advertising Standards Authority, 8 July 2020 (United Kingdom of Great Britain and Northern Ireland).

unsubstantiated environmental statements (Lawyers for Climate Action Complaint to the Advertising Standards Board 2021).[117] In Milieudefensie (2020), The Hague District Court also concluded that Shell had falsely claimed that its plans were aligned with the Paris Agreement. In Denmark, NGOs filed a suit against Danish Crown, a farm cooperative and the European Union's largest pork producer, claiming that the company was misleading consumers through its campaign that claimed its pork production was "climate controlled" and that the pork was "more climate-friendly than you would think." The claimants have alleged that the company is misrepresenting its climate footprint and is in violation of the Marketing Act (*Vegetarian Society et al. of Denmark v. Danish Crown* 2022).[118] The claim is still pending as at 31 December 2022.

Greenwashing claims have also relied on marketing campaigns that are incompatible with a company's investments. For example, a complaint was filed at Ad Standards Australia against HSBC bank for continued fossil fuels investments despite a marketing campaign to support the protection of the Great Barrier Reef (*Complaint to Ad Standards on HSBC's Great Barrier Reef Ad* 2021).[119]

In *FossielVrij NL v. KLM*, several NGOs have challenged the airline KLM's advertising campaign based on the argument that there is currently no such thing as "flying responsibly" and that KLM seeks company growth and increased flight sales when it should be reducing emissions by reducing the number of flights "to keep a just, liveable world within reach." The case builds on an April 2022 decision of the national Advertisement Code Commission, in

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117 *Lawyers for Climate Action Complaint to the Advertising Standards Board*, Advertising Standards Authority Complaints Board, No. 21/194, 6 July 2021 (New Zealand).

118 *Vegetarian Society et al. of Denmark v. Danish Crown*, Western High Court of Denmark, 2022 (Denmark).

119 *Complaint to Ad Standards on HSBC's Great Barrier Reef Ad*, Ad Standards, 0265-21, 13 October 2021 (Australia).

which the Dutch media watchdog ruled that elements of the "Fly Responsibly" campaign violated the code's provisions on misleading advertising, especially those elements referring to climate neutrality or "CO2ZERO". This includes the slogans "Be a hero, fly CO2ZERO" and "CO_2 neutral: KLM compensates for the CO_2 emissions of your KLM Holidays flight" (*Fossielvrij-Beweging v. Koninklijke Luchtvaart Maatschappij N.V.* 2022).[120]

Box 9: Greenwashing complaints – net zero

As more companies commit to net-zero targets, it is likely that questions will be raised as to how these will be implemented. Two cases were filed in Australia and France challenging oil and gas companies' campaigns on net-zero emissions. In Australia, the Australasian Centre for Corporate Responsibility sued oil and gas company Santos over claims that it provides clean energy natural gas and has plans for net-zero emissions by 2040 (*Australasian Centre for Corporate Responsibility v. Santos* 2021).[121] The suit has alleged that these misrepresentations are in violation of Australian consumer protection and corporation laws. In France, several NGOs questioned Total's net-zero advertising campaign, arguing they were false and misleading in their depiction of the role of gas and biofuels. Tv he case was brought under French national law, implementing the European Union's Unfair Commercial Practices Directive and represents the first case challenging an oil and gas major's net-zero claims for greenwashing in Europe (*Greenpeace France, Amis de la Terre France, Notre Affaire à Tous v. TotalEnergies SE, TotalEnergies Electricité, Gaz France* 2022).[122]

C. Protection of consumers: misrepresentation of products

In the United States of America, cases have been brought by cities and states against fossil fuel companies questioning their role in climate disinformation and misrepresentation of products. In *Connecticut v. Exxon Mobil Corp.* (2022), the state of Connecticut sued ExxonMobil to hold the company accountable for violating the Connecticut Unfair Trade Practices Act in connection with alleged deceptive acts to create uncertainty about climate science. In *City of New York v. Exxon Mobil Corp.* (2021), New York City sued several oil companies under the city's consumer protection laws arguing that the companies engaged in deceptive trade practices by misrepresenting their fossil fuel products to consumers, misleading consumers about the impact of fossil fuels. Similarly, in *Vermont v. Exxon Mobil Corp.* (2022), the state of Vermont brought a protection lawsuit against fossil fuel companies alleging deceptive and unfair business practices in connection with the companies' sale of their products.

120 *Fossielvrij-Beweging v. Koninklijke Luchtvaart* Maatschappij N.V., District Court of Amsterdam, 7 July 2022 (Netherlands).

121 *Australasian Centre for Corporate Responsibility v. Santos, Federal Court of Australia,* NSD858/2021, 25 August 2021 (Australia).

122 *Greenpeace France, Amis de la Terre France, Notre Affaire à Tous v. TotalEnergies SE, TotalEnergies Electricité, Gaz France*, Court of Paris, 2 March 2022 (France).

VI. Failure to adapt and impacts of adaptation

Although some governments and private parties are undertaking a variety of measures to adapt to the increasingly severe effects of climate change, others are aware of those changes and the foreseeable extreme weather events that climate change will bring but have not taken steps to prepare. Courts are seeing both cases seeking compensation for adaptation efforts that have caused harm or damaged property and seeking injunctive relief for failing to adapt in the face of known climate risks. However, despite the importance of adaptation efforts, there are still a limited number of cases focused on adaptation. The 2017 and 2020 Litigation Reports described such cases in Australia, Canada, India, Japan, South Africa and the United States of America.

In 2021, a United States of America federal trial court in *Conservation Law Foundation v. ExxonMobil Corp.* (2016) issued an order concerning the next steps for the Conservation Law Foundation's lawsuit that alleged that Exxon failed to prepare its marine terminal in Everett, Massachusetts for the impacts of climate.[123] The district court concluded that a 2021 Supreme Court decision did not alter the standard the district court had used in denying a motion to dismiss claims for prospective injunctive relief for lack of standing. Similar cases have been filed in Rhode Island (*Conservation Law Foundation, Inc. v. Shell Oil Products US* 2022) [124] and Connecticut (*Conservation Law Foundation v. Shell Oil Co.* 2022; *Conservation Law Foundation v. Gulf Oil LP* 2022).[125] These cases are moving forward to trial.

As highlighted in the 2020 Litigation Report, several cases deal with government steps to address the heightened risk of coastal flooding through permitting denials. In 2021, the Supreme Court of Pakistan upheld a notification barring the construction of new cement plants or the expansion of existing cement plants in environmentally fragile zones called "negative areas". In that case, a cement company owner challenged the notification because it violated their constitutional right to freedom of trade, business and profession. The Supreme Court upheld the notification as a climate-resilient measure due to the activities' potential environmental impact, especially on groundwater. The court emphasized the need to consider climate change in government decisions and the impact of climate change on water resources. The court specifically noted the value and need of devising and implementing appropriate adaptation measures to ensure water, food and energy security for the country (*D.G. Khan Cement Company v. Government of Punjab* 2021).[126]

A few other cases have been brought forward due to a Government's lack of consideration of adaptation measures. In *Texans Against High-Speed Rail, Inc. v. U.S. Department of Transportation* (2021), plaintiffs challenged the Federal Railroad Administration's approval of a "Rule of Particular Applicability" for a high-speed rail technology proposed for use in Texas. The plaintiffs included a claim under the National Environmental Policy Act, the EIA law in the United States of America that alleges that the defendants failed to consider how the potential rail project's design would account for increasing rainfall levels resulting from climate change.[127] In *Tsama William and Others v. Uganda's Attorney General and Others* (2020), the applicants question the Ugandan government's lack of adaptation measures against constant landslides related to climate change.

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123 *Conservation Law Foundation v. ExxonMobil Corp.*, District Court for the District of Massachusetts, No. 1:16-cv-11950, 29 September 2016 (United States of America).

124 *Conservation Law Foundation, Inc. v. Shell Oil Products US*, District Court for the District of Rhode Island, No. 1:17-cv-00396, 21 July 2022 (United States of America).

125 *Conservation Law Foundation v. Shell Oil Co.*, District Court for the District of Connecticut, No. 3:21-cv-00933, 16 September 2022 (United States of America).
Conservation Law Foundation v. Gulf Oil LP, District Court for the District of Connecticut, No. 3:21-cv-00932, 29 September 2022 (United States of America).

126 *D.G. Khan Cement Company v. Government of Punjab*, Supreme Court of Pakistan, C.P. 1290-L/2019, 16 April 2021 (Pakistan).

127 *Texans Against High-Speed Rail, Inc. v. U.S. Department of Transportation*, District Court for the Western District of Texas, No. 6:21-cv-00365, 18 August 2021 ((United States of America).

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Part 4: The state of climate change litigation – future directions

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Similar to the 2020 Litigation Report, an analysis of these cases and others, the accelerating impacts of climate change and the global political context suggests several areas where one might expect to see increased climate change litigation in the coming years. As was observed in the same report, although each new case is unique and the outcome of a given case is difficult to predict, prior cases in some of these categories offer some evidence of how future cases may be resolved.

This section first revisits similar trend forecasts, made in the 2017 and 2020 Litigation Reports, of cases involving:

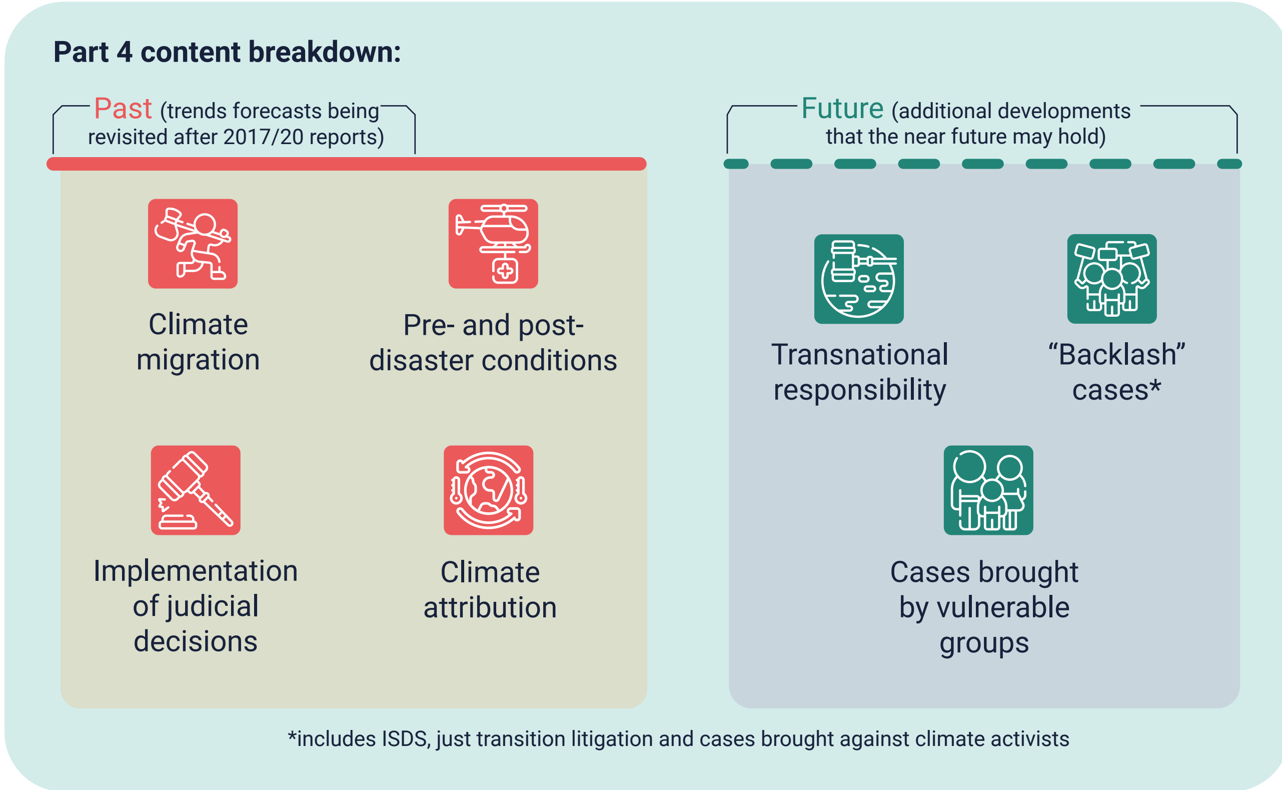
- **(i)** Climate migration
- **(ii)** Pre- and post-disaster conditions
- **(iii)** Implementation of the judicial decisions themselves[1]

It then suggests additional developments that the near future may hold:

- **(iv)** Transnational responsibility
- **(v)** Cases brought by vulnerable groups
- **(vi)** "Backlash" cases, which include ISDS, just transition litigation and cases brought against climate activists

1 With the increase in certain types of cases, some of the categories identified as future directions in the 2020 Litigation Report are now in the current trends. This includes the consumer and investor fraud claims and the increasing use of I nternational adjudicatory bodies.

Figure 10.



I. Update on 2020 predictions: climate migration

The 2017 and 2020 Litigation Reports (UNEP 2017; UNEP 2020) suggested that cases addressing the needs and status of persons displaced by climate change impacts would be a growing litigation trend. Since the 2020 Litigation Report, there has been one important decision in a climate migration case, in Italy. In 2021, Italy's Supreme Court of Cassation ruled in *I.L. v. Italian Ministry of the Interior* that judges evaluating requests for humanitarian protection should consider not only armed conflict but also social, environmental or climate degradation and situations in which natural resources are subject to unsustainable exploitation. That case was brought by a Nigerian national living in the Niger Delta, whose request for humanitarian protection was initially denied. In its decision, the court cited the humanitarian values articulated in the Teitiota case (United Nations, Human Rights Committee 2020), namely that "states have the obligation to ensure and guarantee the right to life of people, and that this right also extends to reasonably foreseeable threats and potentially lethal situations", and concluded that the Niger Delta's severe environmental instability, a result of the indiscriminate exploitation of the area by oil companies and the ethnic-political conflicts, might qualify the plaintiff for humanitarian protection. The court ordered the court of first instance to re-evaluate the application, incorporating into their analysis environmental, climate and resource extraction impacts on an individual's right to life and dignified existence (*I.L. v. Italian Ministry of the Interior and Attorney General at the Court of Appeal of Ancona* 2021).[2]

2 *I.L. v. Italian Ministry of the Interior and Attorney General at the Court of Appeal of Ancona*, Supreme Court of Cassation, N. 5022/2021, 24 February 2021 (Italy).

II. Update on 2020 predictions: pre- and post-disaster cases

Legal actions on the failure to appropriately plan for the consequences of extreme weather events, which are also closely related to adaptation, are likely to increase as the number of such events does.

A few different types of claims have been brought after the occurrence of a disaster or climate change impact, seeking a variety of legal remedies. This was previously addressed in the 2020 Litigation Report where courts were being asked to review a defendant's action or inaction in the face of known risk that climate-related extreme events would result in damage to plaintiffs' property or loss of life. As summarized in that report, the scope of potential liability from cases of this type is broad: any entity that arguably neglected an obligation to plan or prepare for climate-driven damages faces a risk of being sued in the wake of an extreme weather event or after slow-moving climate impacts injure potential plaintiffs. In the Ugandan case *Tsama William and Others v. Uganda's Attorney General and Others* (2020), applicants have sought damages and compensation from the Government for the loss of life, threats to life, destruction of property and infringement of fundamental human rights, as well as the costs of resettlement to safer areas due to occurrence of recurring landslides in Bududa District. The plaintiffs claim that the Government has failed to prevent and properly adapt to climate-driven damages, therefore affecting their human rights. Landslides have been made more frequent and intense as a result of climate-related extreme weather events.

In *Bushfire Survivors for Climate Action Incorporated v. Environmental Protection Authority* (2021), the plaintiffs alleged that they had been harmed by bushfires made likely or more intense by climate change and claimed that the New South Wales Environmental Protection Authority of Australia failed to develop guidelines or a policy to regulate GHGs consistent with limiting global temperature rise to 1.5°C.[3] In 2021, the Land and Environment Court ordered the New South Wales Environmental Protection Authority to develop environmental quality objectives, guidelines and policies to ensure protection from climate change impacts. The court found that the duty to develop environmental protection instruments included specific climate change measures.

In a financial case from 2021, a company constructing a large run-of-river hydroelectric project in the Andes Mountains in Chile filed for bankruptcy in Delaware, United States of America. The company cited significant impacts of climate change, which have impacted the hydrology of the Maipo Valley, where the project is being constructed (*In re Alto Maipo Delaware LLC* 2021).[4] It noted that the rivers that would power the project have seen a substantial drop in water flow, altering the amount of power that can be produced and therefore the financial viability of the project.

Cases addressing extreme weather events are also being filed before those events occur. The *Conservation Law Foundation v. ExxonMobil Corp.* (2016) case discussed earlier, and also highlighted in the 2020 Litigation Report, exemplifies how groups might use existing statutes to seek protection against environmental and public health disasters from climate-related extreme events.[5] In 2021, the Conservation Law Foundation filed two similar citizen suits, *Conservation Law Foundation v. Shell Oil Co.* (2022) and *Conservation Law Foundation v. Gulf Oil LP* (2022). These cases asserted that the defendants' bulk storage and fuel terminals in New Haven, Connecticut violated the Clean Water Act and Resource Conservation and Recovery Act because defendants have not designed, maintained, modified or operated their terminals to account for the numerous effects of climate change, including sea level rise and more frequent and more severe storms.

3 *Bushfire Survivors for Climate Action Incorporated v. Environmental Protection Authority*, Land and Environment Court of Australia, NSWLEC 92 and NSWLEC 152, 5 March 2021 (Australia).

4 *In re Alto Maipo Delaware LLC, Bankruptcy Court for the District of Delaware*, No. 21-11507, 17 November 2021 (United States of America).

5 See the 2020 Litigation Report, page 23.

III. Update on 2020 predictions: implementation challenges

As the number and variety of climate change cases increase, plaintiffs are likely to continue seeking a broad range of remedies. However, the implementation of those remedies remains a challenge across all types of cases. The 2020 Litigation Report pointed out a trend suggesting the increased number of climate change cases would result in judicial orders requiring defendants to take broad action to reduce economy-wide, sectoral or individual source emissions; halt or slow deforestation and land-use change; prevent fossil fuel extraction and protect peatlands; and increase the resilience of communities. It is possible that the implementation or non-execution of such orders will form the basis of legal suits moving forward. For instance, as was also noted in the 2020 Litigation Report (Part 2.III.D), implementation of the court's decision in the Colombian Future Generations case continues to raise challenges (Dejusticia 2019). After the decision in Milieudefensie, Shell decided to move its headquarters to the United Kingdom, potentially making implementation of the decision more challenging (Hurst 2021). Several countries in Europe, in efforts to reduce dependence on Russian energy, have also recently decided to revert to coal due to the aggression by the Russian Federation against Ukraine (Betz 2022). This policy change can have significant consequences in the implementation of systemic mitigation decisions such as Urgenda v. the Netherlands and Neubauer.

IV. Update on 2020 predictions: increased attention to climate attribution and fair share assessments of mitigation

The 2020 Litigation Report predicted that rights-based claims on potential governmental or corporate climate mitigation obligations, as well as cases on climate change liability for private actors, would proceed to their evidentiary phases. It remains that, to prove the existence of an obligation or a breach of duty, plaintiffs or petitioners in some cases will likely have to demonstrate both that their injuries were caused by climate change and that the defendant substantially contributed to climate change. Since 2020, few courts have yet to reach the merits of these types of claims, despite the growing body of science illustrating the connections (Burger, Wentz and Horton 2020). The science of climate attribution continues to be central to climate litigation, and as more cases are filed and reach the merits of the plaintiffs' claims, as was anticipated in the 2020 Litigation Report, there will be increased judicial attention on the matter.

Lliuya v. RWE AG (2022) and Milieudefensie directly make use of attribution studies. Lliuya specifically assesses the corporate responsibility of private GHG emitters (in this case, based in Germany) for

© Flickr / Cibola National Forest and Grasslands the impacts of climate change in a different country (in this case, Peru) (Stuart-Smith *et al.* 2021). In addition, several standing decisions address this for the purposes of injury. In Juliana (2020), the Ninth Circuit Court of Appeals agreed with the district court that the plaintiffs met the injury and causation requirements for standing because at least some plaintiffs had alleged concrete and particularized injuries caused by fossil fuel carbon emissions that were increased by federal subsidies and leases. In *Natural Resources Defense Council v. Wheeler* (2020), the D.C. Circuit Court of Appeals found as a threshold matter that the Natural Resources Defense Council and one of the state petitioners (New York) each had standing based on potential injuries from climate change, which were caused in part by hydrofluorocarbon emissions and would be redressed by restrictions on such emissions.[6]

As plaintiffs rely on the notion of fair share of global emissions under the Paris Agreement to precisely determine a country's obligations to mitigate climate change, it is likely that specific studies will also be relied on in climate litigation cases. For example, in *A Sud et al. v. Italy* (2021), Climate Action Tracker specifically presented a report assessing Italy's fair share in climate mitigation to substantiate the claim to reduce emissions by 92 per cent by 2030 compared with 1990 levels.

V. Transnational responsibility (extraterritorial responsibility)

Increasing discussion on extraterritorial jurisdiction will likely become a central aspect of cases in the future. The previously noted advisory opinion by the IACtHR delineated for the first time the parameters for establishing jurisdiction in cases seeking redress for transboundary environmental harms (IACtHR 2017; Tigre and Urzola 2021). The court reasoned that extraterritorial jurisdiction can be established when (i) there is a factual nexus between conduct within a State's territory and an extraterritorial human rights violation, and (ii) a State exercises effective control over the activities carried out in

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6 *Natural Resources Defense v. Wheeler*, Court of Appeals for the D.C. Circuit, 446 U.S. App. D.C. 93, 955 F.3d 68, 7 April 2020 (United States of America).

another State that caused the harm and consequent violation of human rights in the other State. The recognized nexus broadens a State's responsibility for environmental harms, including climate change, and reflects its obligation to exercise due diligence within its territory when human rights elsewhere are at stake (Murcott, Tigre and Zimmermann 2022).

Using the IACtHR's legal reasoning, the United Nations Committee on the Rights of the Child found in *Sacchi et al. v. Argentina, et al.* (2021) that countries have extraterritorial responsibilities related to climate change. Specifically, when transboundary harm occurs, children are under the jurisdiction of the State on whose territory the emissions originated if (i) there is a causal link between the acts or omissions of the State in question and the negative impact on the rights of children located outside its territory, and (ii) the State of origin exercises effective control over the sources of the emissions in question. The findings provide a significant pathway for future climate litigation beyond the Convention on the Rights of the Child, and its reliance on the interpretation of extraterritorial responsibility by the IACtHR shows a growing cross-fertilization between courts.

One of the key legal questions in *Greenpeace Nordic Ass'n v. Ministry of Petroleum and Energy (People v. Arctic Oil)* (2020) was whether extraterritorial emissions from the combustion or other use of oil exported from Norway were relevant in applying the constitutional right to a healthy environment. The Supreme Court found that emissions are the responsibility of each State within their jurisdictional scope and that the right does not provide protection outside of Norwegian territory (Voigt 2021). However, the court left open the possibility of holding the State responsible for violating its duty to provide a clean and healthy environment for the combustion of its oil exports when (i) the case involves governmental activities or activities performed under the control of the Government of Norway, including when the Government fails to implement measures against polluting activities, and (ii) when direct environmental damage occurs in Norway as a consequence of the activities for which the Government is directly or even indirectly responsible (Gociu and Roy 2021). This interpretation may open the door to responsibility for extraterritorial emissions when GHGs emitted elsewhere from oil and gas exploited in Norway but combusted by companies in another country accumulate in the atmosphere and lead to harm in Norway as well (Gociu and Roy 2021; Voigt 2021). A similar claim can be seen in the case of *Greenpeace Argentina et al., v. Argentina et al.* (2022), in which plaintiffs have argued that the State is responsible for the emissions that arise from fossil fuel exports, in addition to emissions within its own territory.[7]

In *Amis de la Terre and Sherpa v. Perenco* (2022), the Court of Cassation in Paris provided an avenue for establishing extraterritorial responsibility for a French company's actions in the Democratic Republic of the Congo under the Duty of Vigilance statute. The court found that one seeking compensation for environmental damage or subsequent damage may choose to invoke either the law of the country in which the damage occurred or the law of the country in which the event giving rise to the damage occurred. In this case, the event giving rise to the damage originated in France: the environmental damage suffered in the Democratic Republic of the Congo is due to the de facto control and dominant influence of the company (whose head office is in France) over the companies of the group operating in the Democratic Republic of the Congo. Therefore, the right to request measures to preserve or establish evidence relevant for a case questioning environmental liability abroad is defined in the law of the jurisdiction or venue in which legal action is brought (in this case, in France).

Another way to indirectly establish a country's extraterritorial jurisdiction is by including plaintiffs from beyond the particular jurisdiction where the case is filed. These often include plaintiffs from Global South jurisdictions, which are often most vulnerable to climate impacts. Some of the plaintiffs in the German case Neubauer were from Bangladesh and Nepal. The court agreed that it was conceivable that fundamental constitutional rights obliged Germany to protect people in other countries (Peel and Markey-Towler 2022). However, it did not answer the question of whether the rights of the foreign plaintiffs were violated. The court noted that the duty to protect plaintiffs from Nepal and Bangladesh would not necessarily have the same content compared with people living in Germany.

Other pending cases may ultimately expand on the interpretation of extraterritorial responsibility for climate harm, including the *French case Envol Vert et*

7 *Greenpeace Argentina et al., v. Argentina et al.*, Federal Court of Mar del Plata No. 2, FMP 105/202, 5 December 2022 (Argentina).

al., v. Casino (2021), and *Lliuya v. RWE AG* in Germany. These cases are interesting because they relate to the potential damage of companies headquartered and operating in a Global North jurisdiction in jurisdictions in the Global South. Similarly, a recent claim was brought by Indonesian citizens in *Four Islanders of Pari v. Holcim* (2023) in a Swiss court, with a request for the Swiss cement company to (i) provide proportional compensation for climate change-related damages on the Indonesian island of Pari, (ii) reduce CO_2 emissions by 43 per cent by 2030, compared with 2019 levels (or according to findings of climate science in order to limit global warming to 1.5°C), (iii) financially contribute to adaptation measures on Pari.[8] The claim can be seen as novel and unprecedented as it combines two approaches at a transnational level: the reduction of GHGs and compensation for climate damages.

VI. Cases brought by vulnerable groups

While climate change affects people worldwide, it affects them unequally. This has slowly begun to be represented in climate litigation, as plaintiffs from at-risk communities bring cases on behalf of themselves or by representing their communities. This has been more prominent with cases filed on behalf of children, as noted earlier. Indigenous groups and women are also increasingly becoming more active in litigation. As these cases are decided, it is possible that more plaintiffs from vulnerable groups will push for increased government action addressed at their vulnerabilities.

Indigenous Peoples' territories contain nearly 80 per cent of the world's biodiversity (Etchart 2017). While different areas are experiencing different effects of climate change, Indigenous groups are disproportionately affected due to their connection to the land and their specific vulnerability to marginalization on other frontiers, such as economic well-being, food security and other available rights and capabilities. According to the *Report of the Special Rapporteur on the Rights of Indigenous Peoples,* Indigenous Peoples are among those who have least contributed to the problem of climate change, yet they are the ones who suffer the most from its effects (HRC 2017). Many Indigenous Peoples live in areas at greater risk of becoming uninhabitable, such as islands and coastal areas, as well as fragile polar and forest ecosystems. This vulnerability is slowly finding representation in a small but growing number of climate litigation claims (Tigre 2022c). Examples can be found in Argentina, Australia, Canada, Ecuador, France, New Zealand and the United States of America. These pending cases provide insight into how Indigenous-specific domestic legal approaches may shape climate-related adjudication going forward (Marcum 2022).

Overall, the climate litigation cases brought by Indigenous groups have had limited success. In one of the few successful cases so far, a Colombian court recognized the impact of climate change on natural water supply due to mining activities as well as the specific violation of fundamental rights of Indigenous groups due to their relationship with water bodies in accordance with their worldviews (Constitutional Court of Colombia 2017). In *Lho'imggin et al. v. Her Majesty the Queen* (2021), the Canadian Federal Court dismissed a claim brought by Indigenous groups that challenged the government's overall approach to climate change on separation of powers grounds. The court found that climate change is an inherently political issue left to the executive and legislative branches of government. With regard to remedies, the court found that it could not take on a supervisory role to ensure adequate climate laws were passed due to the multifaceted problem of climate change. The court never reached the merits to assess whether inadequate responses to climate change by the Canadian Government breached Indigenous human rights.[9] The decision is currently under appeal. In *Baihua Caiga et al., v. PetroOriental S.A.* (2021), Indigenous groups sued oil company PetroOriental for the climate impacts of gas flaring in Ecuador.[10] Applicants argued that the company has violated several human rights due to the impacts of climate change, including the rights of nature as GHG emissions altered the carbon cycle, and the right to land and territory because their ability to enjoy natural

8 *Four Islanders of Pari v. Holcim*, Office of the Justice of the Peace of the Canton of Zug, 1 February 2023 (Switzerland).

9 *Lho'imggin et al. v. Her Majesty the Queen*, Federal Court of Appeal of Canada, T-211-20, 28 June 2021 (Canada).

10 *Baihua Caiga et al., v. PetroOriental S.A.*, Family, Women, and Children Judicial Unit from Francisco de Orellana Canton, No. 22201202000469, 15 July 2021 (Ecuador).

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resources through ancestral practices has been limited, among others. The court of first instance did not admit the claim as the plaintiffs had not sufficiently demonstrated the violation of rights.

In *Dennis Murphy Tipakalippa v. National Offshore Petroleum Safety and Environmental Management Authority & Anor* (2022), the Federal Court of Australia decided to halt a project for offshore oil drilling near the Tiwi Islands, a biodiversity hotspot, because Indigenous groups had not been properly consulted.[11]

Several claims are still pending as at 31 December 2022. In *Pabai Pabai and Guy Paul Kabai v. Commonwealth of Australia* (2022), First Nation leaders from the Gudamalulgal nation of the Torres Strait Islands have challenged Australia's failure to cut GHG emissions, asserting that the Government's inaction will force their communities into climate migration. The plaintiffs detailed the climate vulnerability of Torres Strait Islander communities, including loss of fisheries, damages due to sea level rises, including to sacred sites and cemeteries, and the impairment of observance of traditional practices and ceremonies. The applicants alleged that the Australian Commonwealth owes a duty of care to Torres Strait Islanders to take reasonable steps to protect them, their culture, traditional way of life and the environment from harms caused by climate change, and that the Government has breached this duty as the targets are inconsistent with the best available science.[12] In *Youth Verdict v. Waratah Coal* (2020), Indigenous youth plaintiffs who were part of the Youth Verdict environment group challenged a coal mining project that would significantly contribute to climate change and limit the cultural rights of First Nations Queenslanders to maintain their distinctive relationship with the land. The case represents the first time that the 2019 Queensland Human Rights Act has been considered in relation to the environmental impacts of a resource project.[13]

In *Mataatua District Māori Council v. New Zealand* (2020), claimants have alleged that New Zealand has breached its obligations to Māori under the Treaty of Waitangi by failing to take adequate steps to reduce its fair share of GHG emissions. The claim relies on the importance of the natural ecosystem to the Māori culture. The claim is pending at the Waitangi Tribunal, the forum where disputes over the

11 *Santos NA Barossa Pty Ltd v. Tipakalippa*, Federal Court of Australia, FCAFC 193, 2 December 2022 (Australia).

12 *Pabai Pabai and Guy Paul Kabai v. Commonwealth of Australia*, Federal Court of Australia, VID622/2021, 31 March 2022 (Australia).

13 *Youth Verdict v. Waratah Coal*, Queensland Land Court, QLC 33, 2020 (Australia).

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performance of the Treaty of Waitangi between Māori and the Government of New Zealand are heard and resolved.[14]

The two petitions currently pending before the United Nations special procedures, previously mentioned in Part 3.I, also include Indigenous petitioners and rely on the rights of Indigenous groups to a claim for increased climate action by the Governments of the Australia and the United States of America. In *Envol Vert et al., v. Casino* (2021), the plaintiffs have requested compensation to Brazilian Indigenous groups for the loss of opportunity and moral damage stemming from Casino Group's failure to adhere to its duty of vigilance in avoiding deforestation and being supplied cattle from deforested areas and farms established on Indigenous territories. In a Brazilian case seeking enforcement of command-and-control measures to curb deforestation in the Amazon rainforest, the petitioner, the public prosecutor's office (Ministério Público Federal) calls for the expulsion of land grabbers in Indigenous lands situated in critical areas of deforestation, known as hotspots (*Ministério Público Federal v. IBAMA* 2020).

VII. Backlash cases

Recent years have witnessed the initiation of several "anti-climate" cases – or backlash cases – which aim to delay or dismantle existing or emerging regulations that promote climate action (Markell and Ruhl 2012; Peel and Osofsky 2020). These include (i) ISDS claims, (ii) just transition litigation and (iii) criminal cases brought against climate activists. Backlash cases will likely continue to be brought to curb advancements in climate change mitigation and adaptation actions.

A. Investor-State dispute settlements

International investment law is gaining increasing attention as a forum for climate change litigation. Arbitration and mediation are becoming important means of resolving climate-related disputes. However, the confidential nature of such processes makes them difficult to examine and quantify. At least 14 climate-related ISDS cases filed between 2010 and 2022 were identified. While these cases do not always contain explicit references to climate change, they all relate directly to the introduction, withdrawal or amendment of a policy measure explicitly developed to meet a country's climate goals.

The need to curb GHG emissions will lead to further asset stranding in developed and developing countries. Aligning national policies with climate needs will inevitably affect investments in the field of fossil fuel infrastructure across the supply chain. Therefore, the more compelling the need to adopt ambitious and abrupt measures to pursue climate objectives, the higher the risk of ISDS cases being brought against host States. ISDS claims do not – at least not directly – aim to suspend or overturn domestic regulation. Rather, the claims seek compensation for the detriment caused by such measures to foreign investors on a case-by-case basis. Moreover, they strictly relate to the violation of standards of protection under investment treaties for the purposes of obtaining monetary compensation.

IPCC noted that these cases may be hindering national mitigation efforts (IPCC 2022). For example, in *Eco Oro Minerals Corp. v. Republic of Colombia* (2021), an arbitration panel at ICSID found Colombia to be in breach of the Free Trade Agreement related to minimum standard treatment due to the actions of the Colombian Government, which continued to encourage Eco Oro with respect to the mining concession despite a potential overlap of the area with the páramo ecosystem, an important carbon sink. The majority considered the Government's delay in delimiting the páramos and its failure to comply with constitutional obligations to protect the ecosystem at the time of the company's investment. The tribunal found that the company had legitimate expectations to undertake the mining exploitation activities in its concession, and that Colombia's delay in regulating the páramos and delimiting its geographical scope was arbitrary and disproportionate, damaging Eco Oro without serving any apparent purpose. The tribunal concluded that Eco Oro was entitled to damages, to be decided at a later date.[15]

On the other hand, two domestic courts in Germany and the Netherlands have significantly limited the ability of corporations to seek compensation for the effects of climate policies on their assets, directly affecting two pending ISDS cases, *RWE v. the Kingdom of the Netherlands* (2021)[16] and *Uniper v. the Kingdom of the Netherlands* (2022).[17] The two arbitration claims against the Netherlands relate to the Government's phase-out of coal by 2030, which the energy companies argue violates the Energy Charter Treaty. In an anti-arbitration injunction brought by the Dutch Government in Germany in *The Netherlands v. RWE and Uniper*, the Higher Regional Court of Cologne declared in September 2022 that both ICSID arbitral claims were inadmissible. The court found the arbitral clause of the Energy Charter Treaty incompatible with the law of the European Union and thus invalid in intra-European Union arbitrations. The court's decision can be appealed. However, after the decision was handed down, the German Government announced that it would take over 99 per cent of Uniper in exchange for which the company agreed to withdraw its ICSID claim against the Netherlands (*The Netherlands v. RWE and Uniper [Anti-arbitration Injunctions]* 2023).[18]

In *RWE and Uniper v. the Netherlands (Ministry of Climate and Energy)* (2022), The Hague District Court held that companies RWE and Uniper could not claim financial compensation from the Government for the mandatory phase-out of coal-fired electricity production. The court ruled that there was no "unlawful interference" with property rights based on the case law of the European Union, and decided that the measures taken by the Dutch State to reduce CO_2 emissions were proportional and that the interests of the companies had been sufficiently considered when adopting the law.[19]

14 *Mataatua District Maori Council v. New Zealand*, Waitangi Tribunal, WAI 2607, 16 January 2020 (New Zealand).

15 *Eco Oro Minerals Corp. v. Republic of Colombia*, ICSID, No. ARB/16/41, 9 September 2021 (ICSID).

16 *RWE v. the Kingdom of the Netherlands*, ICSID, Case No. ARB/21/4, 2 February 2021 (ICSID).

17 *Uniper v. the Kingdom of the Netherlands*, ICSID, Case No. ARB/21/22, Withdrawn, 2022 (ICSID).

18 *The Netherlands v. RWE and Uniper (Anti-arbitration Injunctions)*, Higher Regional Court of Cologne, January 2023 (Netherlands).

19 *RWE and Uniper v. the Netherlands (Ministry of Climate and Energy)*, District Court of North Holland, ECLI:NL:RBDHA:2022:12628; ECLI:NL:RBDHA:2022:12635; ECLI:NL:RBDHA:2022:12653, 30 November 2022 (Netherlands).

B. Just transition cases

Decarbonization strategies to phase out fossil fuels are developed in a context of socioeconomic problems, including inequality and racial injustice. A just transition, perceived from an environmental and labour-driven perspective, is vital to ensure that decarbonization is both successful and fair. It is defined as the shift towards a low-carbon society that ensures the protection of minorities and carbon-dependent communities from undue burdens of the decarbonization costs. This scenario is even more significant in the Global South. The equity piece of global decarbonization policies gives rise to "anti-regulatory" or "defensive" climate litigation (Savaresi and Setzer 2022). Similar to backlash cases, these lawsuits aim to delay or dismantle existing or emerging regulatory measures that promote climate action (Markell and Ruhl 2012; Peel and Osofsky 2020). Just transition cases question the way in which climate policies are developed and implemented or impact the enjoyment of human rights (Tigre *et al.* 2023). With governments adopting decarbonization strategies, it is likely that just transition cases brought by workers and communities in vulnerable situations impacted by these policies will lead to lawsuits questioning potential breaches of their human rights. These cases often centre around the participation of impacted communities in government decisions.

In 2021, the Supreme Court of Chile ruled in *Company Workers Union of Maritima & Commercial Somarco Limited and Others v. Ministry of Energy* (2021) that a just transition strategy was essential for the workers harmed by the loss of their direct and indirect source of employment resulting from Chile's Energy Sector Decarbonization Plan to achieve carbon neutrality by 2050. The court also ruled it was essential for the communities affected by the loss of services linked to the development of the declining thermoelectric activity. The ruling ordered the government authorities to implement a plan for the reinsertion into the labour market of workers affected by the decarbonization process, consulting them in that process and adopting control measures to ensure compliance.[20]

The increasing need for the necessary minerals to develop batteries in renewable energy projects for decarbonization strategies suggests an increase in the cases that question the environmental impacts of mining. This subset of just transition cases is likely to grow in the near future, especially in the Global South, where most transition minerals are located. Claims have recently been brought in Chile (*Regional Government of Atacama v. Ministry of Mining and Other* 2022) questioning the public participation of affected communities in the authorization of the mining project and environmental impacts of lithium mining pushed forward as part of the energy transition.[21]

C. Claims against climate activists

With the backdrop of a growing social movement raising awareness about the impacts of climate change and protesting the lack of government action, the Sabin Center has also started to add to its database cases bringing criminal charges against climate activists. Such cases have so far been observed in Australia, Canada, France, New Zealand, Switzerland and the United Kingdom. In the cases that have already been decided, judges have generally taken the climate crisis into consideration in sentencing. In recent cases, protesters have argued for a reduced sentence or have attempted to avoid criminal or civil sanctions, arguing that civil disobedience is necessary given the state of the climate crisis. For example, in *Police v. Hanafin* (2020), the New Zealand District Court accepted that anthropogenic climate change and its effects are undeniable and that there is a right to freedom of expression, further noting that without activism, change may be too late. However, the judge held that activism does not necessarily mean civil disobedience, and peaceful civil disobedience cannot be condoned where it infringes the genuine existing rights of another. The activists were convicted but discharged without penalty. In *Climate Activists v. Paris Airports* (2021), activists who illegally entered the tarmac at Charles De Gaulle airport and halted airport operations were acquitted because their actions were taken in a "state of necessity" to warn of future danger, namely climate change. As civil disobedience related to climate change continues, it is likely that more similar cases will be brought.

20 *Company Workers Union of Maritima & Commercial Somarco Limited and Others v. Ministry of Energy*, Supreme Court of Chile, 25.530-2021, 9 August 2021 (Chile).

21 *Regional Government of Atacama v. Ministry of Mining and Other*, Court of Appeal of Copiapo, 9-2022, 30 January 2022 (Chile).

Conclusion

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Conclusion

This report has provided a broad overview of current trends in climate litigation, showing how litigation has become a key driver of climate change mitigation and adaptation. The number and variety of climate change cases continues to increase, as does the geographical range in which climate litigation takes place. Key trends identified in the report include:

(i) Ongoing and increasing numbers of cases relying on human rights enshrined in international law and national constitutions to compel climate action

(ii) Challenging the domestic enforcement (and non-enforcement) of climate-related laws and policies

(iii) Seeking to keep fossil fuels and carbon sinks in the ground

(iv) Claiming corporate liability and responsibility for climate harms

(v) Advocating for greater climate disclosures and an end to greenwashing (de Freitas Netto *et al.* 2020) on the subject of climate change and energy transition

(vi) Addressing failures to adapt and the impacts of adaptation

Several cases identified in the previous reports are still pending, suggesting that litigants, courts and international tribunals will be presented with many more opportunities to resolve the pressing dangers created by climate change in the coming years.

This report further identified a series of future trends in global climate litigation, indicating the direction in which it may head in the coming years. First, it is predicted that the number of cases dealing with migrants, internally displaced people and asylum seekers seeking temporary or permanent relocation from their home countries or regions, owing at least in part to climate change, will continue to grow (United Nations, Human Rights Committee 2020). Second, research continues to suggest a growing number of pre- and post-disaster cases premised on a defendant's failure to properly plan for or manage the consequences of extreme weather events. Third, as more cases are filed and some reach a conclusion, implementing courts' orders will continue to raise new challenges. Fourth, courts and litigants will increasingly be called on to address the law and science of climate attribution as both cases that seek to assign responsibility for private actors' contributions to climate change and cases that argue for greater government action to mitigate advance and proliferate. Fifth, courts will continue to be asked to determine whether States can be held responsible for the extraterritorial dimensions of climate change. Sixth, as the impacts of climate change continue to affect Indigenous communities disproportionately, they will likely bring more cases seeking to bring about a change in climate policies or redress for climate harm. Additionally, several backlash cases will continue to be brought to curb advancements in climate change mitigation and adaptation actions, including ISDS claims, just transition litigation and cases against climate activists. Future research will integrate a gender analysis to better determine the involvement of women and girls who are often viewed as victims to the impacts of climate change as opposed to agents of change who, given the necessary resources and opportunities, are strong leaders that fight for climate justice for the benefit of all.

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ANEXO 3

The Law and Science of Climate Change Attribution

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This paper has benefited from presentations at the University of Oregon School of Law Environmental and Natural Resources Law Center's Fall 2017 Works-in-Progress Conference and Princeton University's David Bradford Energy and Environmental Policy Seminar. Special thanks to Michael Gerrard and Corey Lesk for their comments on early drafts, and to the editorial board and staff at CJEL for their extraordinary assistance.

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I. INTRODUCTION

There is overwhelming scientific agreement that human activities are changing the global climate system and these changes are already affecting human and natural systems. The observational record shows that the planet is getting significantly warmer, with eighteen of the nineteen warmest years on record occurring since 2001.[1] Other observed changes include rising sea levels, ocean warming and acidification, melting sea ice, thawing permafrost, increases in the frequency and severity of extreme events, and a variety of impacts on people, communities, and ecosystems. There

1. *State of the Climate: National Climate Report for January 2019,* NOAA NAT'L CENTERS FOR ENVTL. INFO., https://www.ncdc.noaa.gov/sotc/national/ [https://perma.cc/8BDB-CUP9] (last visited Nov. 30, 2019).

are multiple lines of evidence linking these changes to anthropogenic influence on climate.[2]

The consequences of climate change have received increasing attention in recent years, as communities around the world have been hit hard by climate-related natural disasters. The 2017 Atlantic hurricane season was the costliest on record: seventeen named storms, including six major hurricanes, pummeled the Caribbean and southern United States, causing unprecedented flooding and devastation totaling approximately $370 billion (USD) in worldwide damages.[3] That same year, Southeast Asia experienced unusually heavy monsoon rains which killed over 1,200 people and affected over 45 million people across Bangladesh, India, and Nepal.[4] There were also a number of record-breaking wildfires in 2017 and 2018, which claimed hundreds of lives, thousands of structures, and millions of acres in the Western United States, British Columbia, Europe, and Siberia.[5] Other disasters include chart-topping heat waves throughout the Northern Hemisphere, severe droughts in Central and South America and the Middle East, and record-breaking rainfall and flooding events across all continents.[6] Significant advances in

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3. Brian K. Sullivan, *The Most Expensive U.S. Hurricane Season Ever: By the Numbers*, BLOOMBERG (Nov. 26, 2017), https://www.bloomberg.com/news/articles/2017-11-26/the-most-expensive-u-s-hurricane-season-ever-by-the-numbers [https://perma.cc/VM95-LVU6].

4. *Press Release: 16 Million Children Affected by Massive Flooding in South Asia, with Millions More at Risk*, UNICEF (Sep. 2, 2017), https://www.unicef.org/infobycountry/media_100719.html [https://perma.cc/L285-MNNH].

5. *See, e.g.*, Luis Gomez, *California Wildfires: New Records Set by 2018 Fires*, SAN DIEGO UNION-TRIBUNE (Nov. 12, 2018), https://www.sandiegouniontribune.com/opinion/the-conversation/sd-california-2018-wildfires-burn-with-historic-impact-20181112-htmlstory.html [https://perma.cc/E5PV-V6YF]; Dale Kasler, *Worst Wildfire Year Since When? More California Acres Have Burned in 2018 Than the Past Decade,* SACRAMENTO BEE, Nov. 16, 2018, https://www.sacbee.com/latest-news/article221788220.html; *Facts and Statistics: Wildfires*, INS. INFO. INST. (2019), https://www.iii.org/fact-statistic/facts-statistics-wildfires [https://perma.cc/FJ5C-2R8N]; Melissa Etehad, *Wildfires Rage Across Europe as Countries Battle Intense Heat Wave*, L.A. TIMES (Jul. 28, 2018), https://www.latimes.com/world/la-fg-wildfires-europe-20180728-story.html [https://perma.cc/B56L-GBFM]; Andrew Freedman, *Heat Records Fall in the Arctic as Fires Erupt in Sweden and Siberia*, AXIOS (Jul. 19, 2018), https://www.axios.com/heat-wave-records-wildfires-sweden-norway-siberia-b351dce3-b3ef-41ee-b94e-e7833bd224e2.html [perma.cc/KQP2-2V9K].

6. *See* Daniel Levitt et al., *Deadly Weather: The Human Cost of 2018's Climate Disasters—Visual Guide,* THE GUARDIAN (Dec. 21, 2018), https://www.theguardian.com/environment/ng-interactive/2018/dec/21/deadly-weather-the-human-cost-of-2018s-climate-disasters-visual-guide [https://perma.cc/LCE7-JCYF]; Jason Samenow, *Red-hot Planet: All-time*

climate change detection and attribution science—the branch of science which seeks to isolate the effect of human influence on the climate and related earth systems—have continued to clarify the extent to which anthropogenic climate change causes both slow onset changes and extreme events.[7]

The spike in deaths and costs associated with extreme events and the prospect for slow onset changes with irreversible impacts has inspired a marked increase in the number of lawsuits seeking to hold different actors—particularly governments and fossil fuel companies—accountable for their contribution to or failure to take action on climate change. For example, state and local governments across the United States have filed over a dozen lawsuits against major oil and gas producers, alleging that they knowingly contributed to climate change by extracting and selling fossil fuels, obscuring the science of climate change, and fighting policies aimed at mitigating climate change.[8] In Germany, a Peruvian farmer has brought a lawsuit against RWE, the German utility, seeking compensation for damages associated with a melting glacier the farmer alleges are in part attributable to the defendant's direct GHG emissions.[9] Lawsuits have also been filed against various national governments seeking to compel regulations aimed at curtailing the production and use of fossil fuels and otherwise reducing national GHG emissions.[10] These are among the first, not the last, of these types of cases.

Attribution science is central to the recent climate litigation, as it informs discussions of responsibility for climate change. Indeed, detection and attribution science has long been central to climate litigation, from the lawsuit filed in 1986 by New York City and Los Angeles challenging the National Highway Transportation Safety

heat Records Have Been Set All Over the World During the Past Week, WASH. POST (July 5, 2018), https://www.washingtonpost.com/news/capital-weather-gang/wp/2018/07/03/hot-planet-all-time-heat-records-have-been-set-all-over-the-world-in-last-week/ [https://perma.cc/JY6A-DQAU].

7. U. S. GLOBAL CHANGE RESEARCH PROGRAM, CLIMATE SCIENCE SPECIAL REPORT, FOURTH NATIONAL CLIMATE ASSESSMENT (2017) [hereinafter NCA4]. For a more detailed definition, see Section II(A), *infra*.

8. Michael Burger & Jessica Wentz, *Holding Fossil Fuel Companies Accountable for their Contribution to Climate Change: Where Does the Law Stand?*, 74 BULL. OF THE ATOMIC SCIENTISTS 397 (2018).

9. Lliuya v. RWE AG, VG Essen 15.12.2016 (2 O 285/15) (Germany).

10. MICHAEL BURGER & JUSTIN GUNDLACH, U.N. ENV'T PROGRAMME, THE STATUS OF CLIMATE CHANGE LITIGATION 10–26 (2017).

Administration's decision not to prepare an environmental impact statement for the model year 1989 Corporate Average Fuel Economy standard, despite the standard's potential global warming impacts,[11] through the lawsuit filed in January 2019 by traditional cultural leaders from the Ksanka Band of the Ktunaxa Nation and various conservation groups challenging the U.S. Fish and Wildlife Service's decision to approve a silver and copper mine project in Montana without considering new data concerning the threats climate change poses to threatened grizzly bear and bull trout populations.[12] Climate science also plays a central role in policymaking and planning, particularly where decisions need to be made about how to allocate the costs of mitigating and adapting to climate change. Recently, researchers have been developing methodologies to link harmful impacts that were caused or exacerbated by climate change to specific emitters, with an eye towards holding emitters and other responsible parties accountable in court for their contribution to the harms.[13] As the science evolves, so too will its role in the courtroom and in policymaking.

This Article offers a comprehensive, of-the-moment survey of the roles attribution science plays in climate change law and litigation. Our purpose is to provide legal researchers and climate scientists alike with a roadmap and a rundown of the dynamic interactions between attribution science and climate change law, and to indicate some of the ways the fields might influence one another. Part II reviews the current state of attribution science with respect to both slow- and sudden-onset events. Part III describes the role that attribution science has played in recent litigation as well as policy-making and planning activities, focusing primarily on examples from the United States but also drawing on international examples. Part IV discusses future directions in the law and science of climate change attribution, addressing questions such as how attribution science can better support policy-making, planning and litigation; and how plaintiffs and courts can engage with attribution

11. City of L.A. v. Nat'l Highway Transp. Safety Admin., 912 F.2d 478 (D.C. Cir. 1990).

12. Complaint for Declaratory and Injunctive Relief, Ksanka KUPAQA XAʾȽȻIN v. U.S. Fish and Wildlife Serv., No. 9:19-cv-00020-DWM (D. Mont. Jan. 25, 2019).

13. *See, e.g.*, CLIMATE ACCOUNTABILITY INST., THE CARBON MAJORS DATABASE: CDP CARBON MAJORS REPORT 2017 (July 2017); B. Ekwurzel et al., *The Rise in Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers*, 144 CLIMATIC CHANGE 579 (2017).

science to help resolve questions of liability and responsibility for climate change.

II. SCIENTIFIC UNDERPINNINGS

Since the onset of the Industrial Revolution more than two centuries ago, human activities—especially fossil fuel combustion, land use change, and industrial production—have dramatically impacted earth's climate. As a result of human activities, concentrations of radiatively important agents such as GHGs and aerosols have increased significantly. Carbon dioxide (CO_2) concentrations, for example, have increased by more than 40 percent to levels not seen in at least 3 million years.[14] These changes in atmospheric chemistry have triggered widespread warming and other impacts. Global surface air temperature has increased by approximately 1.8° F since 1900, and ocean heat content has increased by approximately $33.5 \pm 7.0 \times 10^{22}$ joules.[15] As the planet has warmed, Arctic sea ice volume in late summer has decreased by more than 50 percent, mass loss from land-based ice sheets has accelerated, and sea levels have risen by approximately 8 inches since 19001 foot.[16] Warming is also leading to phenological changes, such as longer growing seasons, and impacting all human and natural systems.[17] The frequency, intensity and duration of many types of extreme events are changing dramatically as well. For example, record breaking high temperatures are now far more common than record breaking low temperatures, high water levels on coastlines are increasing dramatically, and the frequency of hydrometeorological extremes—both droughts and floods—is also increasing in many regions.[18]

As climate change has become more and more manifest, our understanding of the climate system has advanced dramatically.

14. WMO Greenhouse Gas Bulletin, No. 13 (Oct. 30, 2017).

15. NCA4 (2017), *supra* note 7, at 11, 82, 365. As a point of reference, the increase in ocean heat content is approximately 580 times larger than world total primary energy supply (TPES). *See* INT'L ENERGY AGENCY [IEA], KEY WORLD ENERGY STATISTICS (2018) (finding that world TPES in 2016 was 13,761 Mtoe, which is equivalent to 5.76×10^{20} joules).

16. *See* NCA4 (2017), *supra* note 7.

17. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [IPCC], SPECIAL REPORT: GLOBAL WARMING OF 1.5°C (Valerie Masson-Delmotte et al. eds., 2018).

18. IPCC, WORKING GROUP II CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY 982 (Fields et al eds., 2014) [hereinafter IPCC AR5 WGII].

Multiple lines of evidence, including increasingly robust observational data sets, paleoclimate data, process-models of increasing complexity, and physical understandings all point to the central role of human activity in the climate changes described above. For example, it has become clear that the spatial pattern of observed warming generally matches our theoretical understanding and model projections; specifically, high latitude regions are warming faster than the tropics, and the lower stratosphere is cooling.[19] The spatial pattern, or fingerprint, of the warming is thus consistent with increases in GHG concentrations, not alternative explanations such as volcanoes, incoming solar radiation, or internal climate variability. Our ability to link anthropogenically-induced global warming to local impacts has also improved dramatically. The leading scientific body for climate assessment, the Intergovernmental Panel on Climate Change (IPCC), periodically publishes a synthesis of existing research on climate change detection and attribution. In its most recent assessment, the IPCC concluded that "there is new or stronger evidence for substantial and wide-ranging impacts of climate change" across all climate zones and continents.[20] Similarly, the Fourth National Climate Assessment (NCA4) prepared by the U.S. Global Change Research Program (USGCRP) states that "[e]vidence for a changing climate abounds, from the top of the atmosphere to the depths of the oceans."[21]

Overall, the existing body of detection and attribution research is now quite large and the findings are sufficiently robust to support a wide variety of applications, including many of the policy, planning, and legal functions outlined in Section III. But there are also constraints to this research, such as data gaps and uncertainty about model projections, which make it difficult to identify a clear causal chain between a particular emitter or activity and specific impacts or harms associated with climate change.

Below, we summarize the current state-of-the-art in climate change detection and attribution science. We begin by defining core concepts and explaining the basic data sources and analytical techniques used in this research. Next, we discuss the status of

19. Gabriele Hegerl, Francis Zwiers & Claudia Tebaldi, *Patterns of Change: Whose Fingerprint Is Seen in Global Warming?*, 6 ENVTL. RES. LETTERS 4 (2011).

20. IPCC AR5 WGII at 982.

21. NCA4 (2017), *supra* note 7, at 36.

research with respect to different attribution questions and different types of observed impacts. For each attribution category, we discuss the areas where findings are relatively robust and then identify key challenges and takeaways for the utilization of this research in climate change law and litigation.

A. Core Concepts and Terminology

Generally speaking, detection and attribution is a two-step process used to identify a causal relationship between one or more drivers and a responding system. The first step—detection of change—involves demonstrating that a particular variable has changed in a statistically significant way without assigning cause.[22] This is typically accomplished using observational data and historical records. The second step—attribution—involves sifting through a range of possible causative factors to determine the role of one or more drivers with respect to the detected change. This is typically accomplished by using physical understanding, as well as models or statistical analysis, to compare how the variable responds when certain drivers are changed or eliminated entirely.

1. Scope of Detection and Attribution Research

Detection and attribution with regards to climate change can be broadly defined to encompass a range of research aimed at linking human activities to observed changes in the climate system and corresponding impacts on natural and earth systems. This area of research can be broken down into several interrelated parts or research streams:

> **Linking climate change to anthropogenic drivers:** How are human activities affecting the global climate system?
>
> **Linking impacts to climate change:** How do changes in the global climate system affect other interconnected natural and human systems?
>
> **Identifying the relative contribution of various emission sources and land use changes:** To what extent have different sectors, activities, and entities contributed to anthropogenic climate change?

22. David R. Easterling et al., *Detection and Attribution of Climate Extremes in the Observed Record,* 11 WEATHER CLIMATE EXTREMES 17 (2016); Gabriele C. Hegerl et al., *Good Practice Guidance Paper on Detection and Attribution Related to Climate Change, in* MEETING REP. OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE EXPERT MEETING ON DETECTION AND ATTRIBUTION OF ANTHROPOGENIC CLIMATE CHANGE 2 (Thomas Stocker et al. eds., 2010).

For the purposes of brevity, we refer to these three areas of research as *climate change attribution*, *impact attribution*, and *source attribution*, recognizing that these terms may be defined differently in other papers. This approach is roughly consistent with that taken by the IPCC in past assessments, specifically the division between Working Group I (WGI), which synthesizes research on the physical science basis for anthropogenic climate change, and Working Group II (WGII), which synthesizes research on the observed and predicted impacts of climate change. However, there is no IPCC analog for "source attribution" as that term is defined in this paper,[23] and this third research stream is commonly viewed as a field distinct from the "detection and attribution" research covered in the IPCC reports. Nonetheless, source attribution deals with a fundamental attribution question relevant to some of the law and policy issues described in Section III and therefore warrants discussion in this paper.

We also discuss *extreme event attribution* as a separate category of attribution research. This is because extreme events do not fit neatly into the "climate change attribution" or "impact attribution" categories. Weather is part of the climate system, but extreme events are often discussed as "impacts" of climate change, and there are unique challenges associated with efforts to ascertain the effect of climate change on a particular extreme event. (These challenges bear similarities to the challenges associated with impact attribution).[24]

The line between "changes in the climate system" and "the impacts of climate change" is not always clear. The IPCC defines the *global climate system* as "the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere, and the biosphere, and the interactions between them."[25] This broad definition is necessary to

23. The IPCC does compile some of this data in the WGI report but there is no systematic effort to synthesize research on the relative contributions of different actors or activities to climate change. There is also a third IPCC Working Group (WGIII) that assesses literature on the scientific, technological, environmental, and social aspects of mitigation of climate change.

24. *E.g.*, extreme weather events are discussed in the IPCC WGI report as a source of evidence for climate change attribution, but also in the IPCC WGII report as an example of how climate change will affect human and natural systems.

25. IPCC, WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 1451 (Stocker et al. eds., 2013) [hereinafter IPCC AR5 WGI].

capture the highly interconnected nature of these components: changes in ocean heat content (hydrosphere), sea ice (cryosphere), carbon sequestration (biosphere), and volcanic eruptions (lithosphere) can all affect the atmosphere and vice versa. The variables studied in this research are often referred to as *essential climate variables.*[26]

The IPCC defines *impacts* or *effects* to include *physical impacts* such as floods, droughts, and local sea level rise, as well as any other "effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period."[27] In many cases, a change in an essential climate variable (e.g., sea level rise) could be viewed as a "physical impact" of climate change. For the purposes of this paper, we classify studies on regional changes in essential climate variables as "climate change attribution" where the primary goal of the study is to better understand how humans are affecting the global climate system, and we classify studies on floods, droughts, and local sea level rise as "impact attribution" where the primary goal of the study is to better understand how climate change is affecting a particular region or locale.

It is also important to note that the IPCC uses a different definition of "attribution" when discussing research on climate change attribution (WGI) and impact attribution (WGII): whereas "attribution in WGI quantifies the links between observed climate change and human activity, as well as other external climate drivers," attribution in WGII "generally links responses of natural and human systems to observed climate change, *regardless of its cause.*"[28] This reflects standard practice in impact attribution studies, wherein scientists focus exclusively on the relationship between global climate change and observed impacts without seeking to identify the relative contribution of human activity as compared with other external climate drivers.

These different streams of attribution science have begun to converge in recent years. There have been further advances in

26. *The Global Observing System for Climate Essential Climate Variables Data Access Matrix,* NOAA NAT'L CENTERS FOR ENVTL. INFO, https://www.ncdc.noaa.gov/gosic/gcos-essential-climate-variable-ecv-data-access-matrix [https://perma.cc/4ZSH-CMGX] (last visited Dec. 19, 2019).

27. IPCC AR5 WGII, Summary for Policy Makers, *supra* note 20, at 5.

28. *Id.* at 4.

attribution of climate change to anthropogenic activity, as well as burgeoning studies that go beyond the analysis of essential climate variables to examine adverse effects on human systems and public health.[29] Simultaneously, other researchers have been compiling data and developing techniques to identify the relative contribution of different sectors, activities, and entities to changes in atmospheric GHG concentrations.[30] Building on all three research streams, there is now a body of research which aims to link specific entities and/or activities to specific climate change impacts.[31] Below, we bring the streams together, contextualizing them within a broader climate science and risk management context.

2. Data Sources and Analytical Techniques

a. Climate Change, Extreme Event, and Impact Attribution

There are several key sources of information and analytical techniques which are used in the climate change, impact, and extreme event attribution studies. These include: physical understanding, observational data, statistical analysis, and models.[32]

Physical understanding refers to scientific understanding of physical properties and processes. A good example would be the heat trapping effects of GHGs, which can be tested using laboratory and modeling experiments. Physical understanding serves as the basis for developing experiments to evaluate potential interactions across variables in the climate system and related human and natural systems.

Observational data is data which can be observed and measured. Examples include in situ measurements of CO_2 concentrations, surface temperatures, and sea levels; satellite measurements of sea

29. Below, we use the phrase "attribution of harm" to describe studies seeking to link specific harmful impacts on public health and human systems to anthropogenic climate change. This is discussed as a subset of "impact attribution."

30. *See, e.g.*, B. Ekwurzel et al., *supra* note 13, at 579.

31. *See, e.g.*, Richard Heede, *Tracing Anthropogenic Carbon Dioxide and Methane Emissions from Fossil Fuel and Cement Producers, 1854–2010*, 122 CLIMATIC CHANGE 229 (2014).

32. *See, e.g.*, Sophie Marjanac & Lindene Patton, *Extreme Weather Event Attribution Science and Climate Change Litigation: An Essential Step in the Causal Chain?*, 36 J. ENERGY & NAT. RES. L. 265, 271–72 (2018) (noting that the "3 pillars of attribution science" are "(i) the quality of the observational record; (ii) the ability of models to simulate the event; and (iii) our understanding of the physical processes that drive the event and how they are affected by climate change.").

surface temperature, water vapor, precipitation, and sea ice; and aircraft measurements of cyclone wind speed. Observational data is primarily used in conjunction with statistical analysis to detect changes in the climate system, including changes in the frequency and severity of extreme events, and corresponding changes in natural and human systems—specifically, by comparing historical observational data sets with contemporary observations of a particular variable and determining whether there has been a statistically significant change in that variable. A statistically significant change would be detected in observations if the likelihood of occurrence by chance alone is determined to be small (e.g., less than 10%).[33]

Statistical analysis refers to mathematical formulas, models, and techniques that are used in empirical analysis of data. Statistical analysis is used in both the detection and attribution of climate change. For attribution, statistical analysis is used to quantify the probability of an observed change occurring with and without anthropogenic forcing on the climate. For example, scientists use linear regression methods[34] and variants such as "optimal fingerprinting" to determine whether a change in a climate variable is statistically significant or simply part of natural variability.[35] This analysis is part of the detection of climate change and corresponding impacts, but it can also be used to support attribution statements (e.g., a finding that the spatial pattern of warming in the atmosphere was likely caused by anthropogenic emissions because it is statistically unlikely that the spatial pattern would have occurred in the absence of anthropogenic forcing on the climate). This is sometimes referred to as "observation-based" attribution.[36]

In practice, there are very few studies that focus exclusively on observation-based statistical analysis for attribution due to short observation records and complex forcing changes over the

33. IPCC, CLIMATE CHANGE 2014: SYNTHESIS REPORT 121–22 (Rajendra K. Pachauri & Leo Meyer eds., 2014) [hereinafter IPCC AR5 SYR].

34. Linear regression is a statistical method used to summarize and study relationships between two continuous (quantitative) variables.

35. K. Hasselmann, *Optimal Fingerprints for the Detection of Time-Dependent Climate Change*, 6 J. CLIMATE 1957, 1957 (1993).

36. NAT'L ACAD. OF SCI., ENG'G, AND MED., ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE 51 (2016).

historical period.[37] Model approaches (below) are typically used because: (i) models allow scientists to separate out the effects of different forcings on the observed variable, and (ii) the observed record for many variables is too short to support reliable conclusions, especially given the large variability in the systems being analyzed. That said, observation-based attribution findings can serve as a useful supplement to model-based findings.[38]

Models use quantitative methods, including predictive equations and statistical techniques, to simulate interactions within the climate system. Scientists can thus set up different model experiments to evaluate the effect of one or more climate drivers (like greenhouse gases, aerosols, and solar flux) on one or more variables. For the purposes of attribution, experiments with climate models generally involve at least two sets of simulations, differing only in that one is meant to reflect the world that is, and the other is meant to reflect a "counterfactual" world without anthropogenic climate change (or without some component of anthropogenic climate change). These model simulations are typically run multiple times and for long duration, allowing scientists to better understand the most likely outcomes, as well as a fuller range of potential outcomes. Observational data and physical understanding provide the basis for calibrating and verifying models.

Several modeling centers have now developed standardized climate simulations designed for detection and attribution specifically, based on different parameters (e.g., researchers can evaluate the probability of an event or impact occurring both with and without certain observed changes in the climate, such as changes in sea surface temperature). Due to advances in parallel computing and model simplifications, these can be run rapidly and at high spatial resolution, yielding quick results. Indeed, when the above packages are combined with forecasts of variables with high predictability, such as sea surface temperature, results can be made available *in advance* of actual events. Furthermore, the tools and outputs, and models themselves, are increasingly being made publicly available. This has furthered the proliferation of

37. *Id.*

38. Andrew D. King et al., *Attribution of the Record High Central England Temperature of 2014 to Anthropogenic Influences*, 10 ENVTL. RES. LETTERS, May 1, 2015, at 1; Gabriele C. Hegerl, *Use of Models and Observations in Event Attribution*, 10 ENVTL. RES. LETTERS July 2, 2015, at 1.

attribution research in recent years, as well as an enormous amount of media coverage and public interest in the topic.[39]

Model-based approaches can support more robust attribution statements than the use of observational data and statistical analysis alone. However, models have limitations that should be kept in mind when considering their use in attribution studies. The usefulness of a model for attribution depends on how well the model can reproduce patterns associated with each climate forcing. However, there are uncertainties in our knowledge about how individual climate forcings affect the climate system. While comparing models to observations helps assess model skill, observations cannot tell us all we need to know, for three reasons. First, there is some uncertainty in observational measurements. Second, internal climate variability, unrelated to climate forcing, is difficult to disentangle from climate forcing. Third, because multiple anthropogenic and natural forcings have occurred simultaneously in the past, unpacking the relative contribution of each forcing is nontrivial.

The above challenges exist to a certain degree even for variables like global average temperature where the relationship between rising GHG concentrations and average temperatures is fairly direct. Inevitably, there will be some degree of uncertainty and room for error in model results due to the complexity of the physical systems being modeled.[40] But this does not mean that model results are unsound. To the contrary, uncertainty is prevalent across many scientific disciplines, including disciplines that are frequently relied upon in policy, planning, and litigation,[41] and scientists have tools for managing and communicating uncertainty. The IPCC, for example, uses (i) probabilistic language to describe the assessed likelihood of an outcome or result (very likely, likely, etc.);[42] (ii) terms to describe the availability of evidence to support particular findings (limited,

39. See, e.g., Jane C. Hu. *The Decade of Attribution Science*, SLATE (Dec. 19, 2019).

40. E.g., models may underestimate variability, which can lead to overestimation of the effect of human influence on extreme events, and models may under-sample the range of plausible outcomes.

41. E.g., epidemiology and forensic science.

42. The IPCC defines these probabilistic terms as follows: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. In some instances, the IPCC also uses the following terms: extremely likely 95–100%, more likely than not > 50–100%, and extremely unlikely 0–5%. IPCC AR5 WGI, *supra* note 25, at 4.

medium, robust); (iii) terms to describe the level of agreement about findings (low, medium, or high); and (iv) language describing its confidence in the findings (very low, low, medium, high, very high).[43] In individual attribution studies, uncertainty is typically managed and communicated using similar statements about confidence levels and intervals. For example, a study may conclude with 90% confidence that climate change made an extreme event at least twice as likely to occur.[44] Scientists are also constantly refining the techniques used to reduce uncertainty in their analyses, such as through additional and lengthened observational datasets, improvements to models, new analytical methods, and expert judgment.

The most robust attribution approaches combine good observations, physical understanding, rigorous statistical analysis, and detailed models to generate findings, along with clear communication and transparency with respect to research parameters, assumptions made, confidence in findings, and potential areas of uncertainty or bias. Studies that combine sound science with clear communication can generate findings that are sufficiently robust to support a wide variety of applications, but the confidence in and precision of those findings depends on the nature of the change, event, or impact being studied.

b. Special Considerations for Extreme Event and Impact Attribution

Attribution becomes increasingly complex and challenging as the focus of research moves away from long-term, broad-scale changes in the climate system and towards more localized, discrete extreme events and climate impacts. One key challenge is conducting the analysis at the appropriate *spatial and temporal scale*. Whereas climate change attribution as defined in Part II(A)(2)(a) above deals with change at a global or regional scale, typically over a long period of time, extreme event and impact attribution deal with more geographically and temporally distinct forms of change (e.g., how much has sea level risen in a particular city in the past twenty years). Natural variability, unrelated to changes in climate forcing, is larger at fine spatial and temporal scales, making it harder to

43. *Id.*
44. In this statement, the confidence level is 90% and the confidence interval starts at "twice as likely" and has no defined upper bound.

identify signals associated with anthropogenic or other forcings. Some climate forcings, such as aerosols, also differ both in concentration and forcing strength at subregional and subannual scales. Additionally, when models are used to assess extreme events that occur at finer spatial and temporal scales than the models themselves, some type of downscaling or bias correction is needed, which can introduce additional uncertainties.

Impact attribution studies must also account for *non-climate variables*—that is, characteristics of human and natural systems that are not part of the climate system. There are sometimes referred to as *exogenous variables* (i.e., phenomena that are not part of the climate system).[45] Consider a study examining the relationship between climate change, a heat wave, and public health impacts: the study would need to account for both climate variables (e.g., temperature and humidity) as well as non-climate variables (e.g., population risk factors for heat-related morbidity, access to air-conditioned facilities and emergency services) to ascertain the extent to which climate change caused or contributed to observed health outcomes. *Confounding variables*, which influence both dependent and independent variables in a study, are of special concern as they can lead to spurious associations between a driver and an event or impact.[46] The number of exogenous and confounding variables increases as attribution research moves towards an analysis of discrete impacts on humans, communities, and ecosystems.

Due to the difficulty of managing many exogenous variables, most attribution studies focus on just one "link" in the causal chain of anthropogenic climate change. This is often referred to as *single-step attribution*. Examples of single-step attribution include research linking increases in global average temperatures to changes in the atmospheric concentration of GHGs, and research linking increases in local sea level rise to increases in global average temperature. This focus on single-step attribution is apparent in IPCC WGII's approach to impact attribution (which, as noted

45. This may be somewhat of an oversimplification, as many variables which may appear to be "outside" of the climate system are still, to some extent, interdependent with that system.

46. In an impact or event attribution study, the dependent variable would be the impact or event under examination, and the independent variable would be the climate change-related driver of the impact or event (e.g., increases in GHG concentrations or, in some studies, increases in climate variables such as mean temperature).

above, examines how observed climate change is affecting natural and human systems, regardless of its cause).[47]

There is also a growing body of *multi-step attribution* studies. Such studies combine the two inquiries described above: scientists will first seek to identify how one or more core climate variables has changed in response to human activities, and then explore the implications of that change with respect to one or more specific impacts.[48] Multi-step attribution is useful for examining causal relationships in complex systems, but one potential drawback of this approach is that additional, "cascading" uncertainty and potential for error is introduced with each new "step" that is added to the analysis.

c. Source Attribution

Above, we note that source attribution is a distinct field of research that employs different methods and is subject to different constraints. There is some overlap in terms of the data collection and analytical techniques used for source attribution: scientists will use observational data to identify sources of GHGs, as well as physical understanding, statistical analysis, and models to ascertain the relative contribution of GHGs from a particular source or source category to anthropogenic climate change. But source attribution studies also rely on different types of evidence, particularly documentary evidence of GHG emissions and carbon sequestration impacts.[49]

Documentary evidence refers to information contained in documents and reports. For the purposes of source attribution, key sources of documentary evidence include national GHG emissions inventories, corporate GHG disclosures, securities disclosures, and other reports prepared by governments and private actors detailing GHG emissions or carbon sequestration impacts from a particular activity or source. Because such reports are prepared by humans, sometimes pursuant to a political or social agenda, they may

47. IPCC AR5 WGII, *supra* note 20, at 4 n.5.

48. IPCC AR5 WGI, *supra* note 25, at 867–952; Gabriele Hegerl et al., *Good Practice Guidance Paper on Detection and Attribution Related to Anthropogenic Climate Change, in* MEETING REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE EXPERT MEETING ON DETECTION AND ATTRIBUTION OF ANTHROPOGENIC CLIMATE CHANGE 3 (Thomas F. Stocker et al. eds., 2010).

49. For a more detailed discussion of the methods and techniques used in source attribution, see *infra* Part II(B)(4).

contain biases or errors of a different type than those found in raw data.

Source attribution also involves questions that cut across different social and scientific disciplines. Certainly, there is a physical science component to source attribution, as the ultimate goal is to ascertain the physical contribution of the source to anthropogenic climate change. But there are also social and normative questions that come into play when attributing emissions (or sequestration) to a particular source, particularly when trying to assign "responsibility" for emissions. Consider the many different ways that emissions can be "divvied up" across different lines—by stage of economic development, global region, country, sector, company, consumer, etc. Even within these categories, there are different ways of assigning emissions responsibility. For example, when assessing national responsibility for climate change, some have argued that we should not only look at emissions which are directly generated within the country ("territorial emissions") but also consider emissions embodied in products consumed within the country ("consumption-based emissions").[50] Similarly, when assessing corporate responsibility for climate change, there are important questions about the relative responsibility of upstream entities (e.g., fossil fuel producers) and downstream entities (e.g., manufacturers of carbon-intensive products and consumers of fossil fuels) in addition to the entities that directly generate emissions.

Granted, it is entirely possible to avoid such normative questions when publishing information about source attribution. For example, a study could simply provide a breakdown of emissions across different countries (perhaps both CO_2 exporters and CO_2 importers), sectors, etc., without reaching any conclusions about the *responsibility* of different actors or source categories. But in practice, when attribution science is related to law and policy, the question of responsibility is of paramount importance.

50. *See, e.g.*, C40 CITIES CLIMATE LEADERSHIP GROUP, CONSUMPTION-BASED GHG EMISSIONS OF C40 CITIES (2018), https://www.c40.org/researches/consumption-based-emissions [https://perma.cc/9XVC-MCRX]; Zeke Hausfather, *Mapped: The World's Largest CO2 Importers and Exporters*, CARBON BRIEF (May 7, 2017, 11:52 AM), https://www.carbonbrief.org/mapped-worlds-largest-co2-importers-exporters [https://perma.cc/3K2V-EFNE]; DANIEL MORAN ET AL., THE CARBON LOOPHOLE IN CLIMATE POLICY: QUANTIFYING THE EMBODIED CARBON IN TRADED PRODUCTS (2018), https://buyclean.org/media/2016/12/The-Carbon-Loophole-in-Climate-Policy-Final.pdf [https://perma.cc/FS95-N9W4].

B. Survey of Research to Date

1. Climate Change Detection and Attribution

Climate change detection and attribution research examines the effect of human activities on the global climate system, which is broadly defined to include the atmosphere, hydrosphere, cryosphere, lithosphere, biosphere, and the interactions between these components. The primary research question is: how do human-induced changes in the chemical composition of the atmosphere affect other essential climate variables such as temperature, precipitation, sea level, and sea ice? To answer this question, researchers must demonstrate that a detected change is "consistent with the estimated responses to the given combination of anthropogenic and natural forcing" and "not consistent with alternative, physically plausible explanations of recent climate change that exclude important elements of the given combinations of forcings."[51]

The existing body of research leaves little room for doubt that the global climate system is changing and human activities are at least partially responsible for that change; thus, there is no real question as to *whether* anthropogenic climate change is occurring. Scientists have also made considerable progress towards quantifying the effect of human activities on different components of the climate system. However, there is still some amount of uncertainty about the magnitude of the observed changes in the climate system that are due to different climate forcings—such as GHGs, aerosols, and solar radiation.[52] In this section, we

51. IPCC, WORKING GROUP I CONTRIBUTION TO THE THIRD ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2001: THE SCIENCE OF CLIMATE CHANGE 56 (John T. Houghton et al eds., 2001). While in one sense attribution is easy to define, complex philosophical questions lurk in the background, including the question of how one defines causation. Deterministic causation is a simple binary framing ("A caused B") whereas probabilistic causation has a lower threshold of "A made B more likely than in otherwise would have been." Mike Hulme, *Attributing Weather Extremes to 'Climate Change': A Review*, 38 PROGRESS IN PHYSICAL GEOGRAPHY 499, 500 (2014). Even within the sub-branch of probabilistic causation, emphasized here, it should be noted that the way a problem is framed can influence the findings. See for example, the description of necessary vs. sufficient causality in Alexis Hannart et al., *Causal Counterfactual Theory for the Attribution of Weather and Climate-Related Events*, 97 BULL. AM. METEOROLOGICAL SOC'Y 99, 103–04 (2016).

52. These uncertainties primarily concern: 1) the magnitude of change in other possible drivers of climate changes (such as solar radiation changes); 2) the signature of change expected in the climate system due to human activities and '1' above; and 3) the magnitude of internal climate variability. IPCC AR5 WGI, *supra* note 25, at 867–952.

summarize the state of the terms of observed climate changes and the attribution of those changes to human activities. We focus here on mean changes in essential climate variables on a global and regional scale; changes in extremes and changes in local weather and climate are discussed in subsequent sections.[53]

a. Methods and Parameters

Scientists detect changes in the climate system through in situ measurements, such as the CO_2 readings from the Mauna Loa Observatory in Hawaii, and remote sensing from satellites and other platforms. Some of the key types of data collected through observations include measurements of GHG emissions and concentrations, atmospheric and surface temperature, water vapor (humidity), precipitation, sea ice, and sea levels. Scientists have also developed techniques to better understand past climatic conditions—for example, scientists can reconstruct paleoclimate conditions by studying the patterns in tree rings and gas bubbles trapped in ice cores.[54] This information offers important insights, including: 1) how sensitive different aspects of the climate system are to different climate forcings at various timescales, and 2) more robust estimates of natural variability than can be gleaned from the relatively short observational record.

Once change has been detected, the next step is attribution. Physical understanding of how the climate system reacts to different forcings is the foundation of climate change attribution. Examples of external forcings include GHGs, atmospheric aerosols, solar radiation, and reflectivity (albedo), all of which influence the balance of energy in the global climate system. Scientists must also have physical understanding of natural variability within the global climate system in order to ascertain whether an observed change in the system is the result of changes in forcings or natural variability.

Drawing on this physical understanding, scientists have developed global climate models that reproduce physical processes in the atmosphere, ocean, cryosphere, and land surface. One of

53. *See infra* Part II(B)(2) ("Extreme Event Attribution") and Part II(B)(3) ("Impact Attribution").

54. For more information on the development of observational techniques and datasets, see IPCC, WORKING GROUP I CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE IPCC, Climate Change 2007: The Physical Science Basis 93–127 (Susan Solomon et al. eds., 2007).

the most important modeling initiatives is the Coupled Model Intercomparison Project (CMIP), which was launched by the World Climate Research Programme in 1995 to foster collaboration on and ongoing improvement of climate models and to provide a standard set of model simulations to facilitate comparison across models. Leveraging ongoing advances in physical understanding, observations, and computational power, climate models now operate at finer and finer spatial scales, include interactions across more and more components of the climate system, and generate thousands of years of model output under different forcings and initial conditions. As models have grown in sophistication, their utility for climate attribution has grown—models driven by historical greenhouse gas emissions and natural forcings (e.g., volcanoes and solar variability) can now "reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions."[55]

As noted above, there are challenges associated with "downscaling" from a global to a regional or local focus. These challenges are most prevalent in extreme event and impact attribution, but they also appear, to a lesser extent, in climate change attribution studies. This is because many of the observed changes in the global climate system vary on a regional basis—both due to differences in forcings and the higher natural variability at finer spatial scales.[56]

b. Status of Research

The observational record shows that significant changes in the global climate system are occurring. As noted in the IPCC's Fifth Assessment Report (AR5):

55. The IPCC issued this statement with *very high confidence*. IPCC AR5 WGI, Summary for Policymakers, *supra* note 25, at 15.

56. Above, we define "climate change attribution" as research aimed at determining "how human activities are affecting the *global* climate system." Thus, this section is concerned only with studies seeking to understand and attribute regional changes in essential climate variables in order to better understand changes in the global climate change. This section does not discuss studies that evaluate how climate and weather has changed in a region or locale in order to ascertain the effect on that region or locale (e.g., how much have sea levels risen in New York City?)—rather, those are discussed in the extreme event and impact attribution sections.

> Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.[57]

AR5 contained similarly conclusive findings about climate change attribution, particularly with respect to the link between human influence on climate and global warming:

> Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.[58]

The report also found strong evidence that human activity had contributed to changes in other essential climate variables, such as sea level rise and the loss of sea ice, with different levels of confidence for different variables.[59]

Since AR5 was published in 2014, the observational record of changes in the global climate system has become even more robust, and the rate of observed change has accelerated for many essential climate variables. The body of research attributing these changes to anthropogenic influence on climate change has likewise become more robust, with more recent attribution studies further reinforcing some of the key messages from AR5. Below, we summarize the latest findings in terms of observed changes and attribution to human activity.[60]

i. Chemical Composition of Global Climate System

AR5 found, with *very high confidence*, that atmospheric concentrations of CO_2, methane (CH_4), and nitrous oxide (N_2O)

57. IPCC AR5 WGI, Summary for Policymakers, *supra* note 25, at 4.
58. *Id.* at 15.
59. *Id.*
60. There have been additional advances in the detection and attribution of long-term, time averaged climate variables that do not fit neatly into the five directly societally-relevant categories described here. Examples include fingerprinting of sea level pressure, Nathan P. Gillett, Francis W. Zwiers, Andrew J. Weaver & Peter A. Stott, *Detection of Human Influence on Sea-level Pressure*, 422 NATURE 292, 292–94 (2003), and water vapor, Benjamin D. Santer et al., *Incorporating Model Quality Information in Climate Change Detection and Attribution Studies*, 106 PROC. OF THE NAT'L ACAD. OF SCI. 14778, 14778–83 (2009).

are higher than they have been in 800,000 years, and that the rate of change in GHG concentrations over the past century is unprecedented in the past 22,000 years.[61] This was based on observations from 2011 (the latest data relied upon in AR5), showing that CO_2 concentrations had increased 40% to 391 parts per million (ppm), methane (CH_4) concentrations had increased 150% to 1803 parts per billion (ppb), and nitrous oxide (N_2O) concentrations had increased 20% to 324 ppb, as compared with pre-industrial levels.[62] This trend has continued since AR5 was published, with the latest in situ measurements putting CO_2 concentrations at 410.5 ppm, methane concentrations at 1862.8 ppb, and nitrous oxide concentrations at 332.4 ppb.[63]

Not all of these GHGs remain in the atmosphere, which is part of why it is necessary to look at multiple interconnected systems when detecting and attributing global climate change. AR5 found that the ocean had absorbed about 30% of the emitted anthropogenic CO_2, approximately 125–185 gigatons of carbon (GtC).[64] The uptake of carbon has caused ocean acidification: the pH of the ocean surface has decreased by 0.1 since the beginning of the industrial era, which corresponds with a 26% increase in hydrogen ion concentration (the measure of ocean acidity).[65] This acidification is relatively straightforward to attribute to anthropogenic carbon dioxide emissions specifically.[66] Terrestrial

61. IPCC AR5 WGI at 385. The IPCC also expressed medium confidence that the rate of GHG change was unprecedented in the past 800,000 years. These findings were based on paleoclimate observations from ice cores. *Id.* At the time AR5 was published, ice core records only extended back 800,000 years, so it was not possible to reach conclusions about GHG concentrations before this time. In 2017, scientists extracted a record-breaking 2.7-million-year-old ice core which indicated that CO_2 levels were also well below current levels during that time period. Paul Voosen, *2.7-million-year-old Ice Opens Window on Past*, 357 SCIENCE 630 (2017).

62. IPCC AR5 WGI at 678.

63. *Trends in Atmospheric Carbon Dioxide*, NOAA NAT'L CENTERS FOR ENVTL. INFO., https://www.esrl.noaa.gov/gmd/ccgg/trends/gl_trend.html [https://perma.cc/JKJ5-5GSV] (last visited Dec. 5, 2019); *Global CH_4 Monthly Means*, NOAA NAT'L CENTERS FOR ENVTL. INFO., https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/ [https://perma.cc/8AE3-RWTJ] (last visited Dec. 5, 2019); *Nitrous Oxide (N2O)—Combined Data Set*, NOAA NAT'L CENTERS FOR ENVTL. INFO., https://www.esrl.noaa.gov/gmd/hats/combined/N2O.html [https://perma.cc/K483-DBHR] (last visited Dec. 5, 2019).

64. IPCC AR5 WGI, Summary for Policymakers, *supra* note 25, at 11–12.

65. *Id.* at 12.

66. *Id.* Bindoff describes it as 'very likely.' *Id.* at 870. In the same report, another ocean chemistry change, a global decrease in dissolved oxygen especially in near-coastal waters, was assessed with medium confidence to be attributable "in part to human influences." *Id.*

ecosystems are also absorbing CO_2, but there is significant uncertainty as to the actual quantity sequestered: research indicates that anywhere from 70–250 GtC have accumulated in terrestrial systems.[67] Accounting for these different absorption pathways is critical in all aspects of climate change detection and attribution (including extreme event and impact attribution) because the effect of GHGs is dependent on where those gases are stored. Uncertainties about historical storage, or sinks, leads to some uncertainty about the magnitude of total historical effect of anthropogenic sources on climate change. More importantly, a changing climate could weaken important sinks. For example, a warming ocean is able to absorb less CO_2, melting permafrost and hydrates could release ancient CO_2 and methane to the atmosphere, and changes in vegetation could increase or decrease the terrestrial carbon sink.

ii. Atmospheric and Surface Temperature

As noted above, AR5 found "unequivocal" evidence that the climate system is warming, concluding that it was "certain" that global mean surface temperature (GMST) had increased since the late 19th century, and "virtually certain" that the global troposphere had warmed since the mid-20th century.[68] With regards to attribution, AR5 noted that observed warming trends were consistent with physical understanding and models of how rising atmospheric GHG concentrations would affect the climate system, and that the trends could not be explained by other forcings or natural variability alone.[69] AR5 quantified the potential contribution of human influence as follows:

67. *Id.* at 12.

68. *Id.* at 4, 161–62. At that time, the observational record showed that: (i) each of the last three decades had been successively warmer, in terms of global surface temperatures, than any preceding decade since 1850, and the first decade of the 21st century was the warmest on record; and (ii) globally averaged combined land and ocean surface temperature had increased by 0.85 [0.65–1.06]°C from 1880 through 2012. *Id.* at 161–62.

69. *Id.* at 869. For example, in terms of natural variability, Atlantic Multidecadal Oscillation (AMO) variability can influence trends, but does not explain 1951–2010 warming. In terms of the magnitude of other possible forcings, only solar radiation changes have been in the direction that would be expected to lead to warming, but the magnitude of change over the period is too low to have contributed to much of the warming. Furthermore, the spatial pattern of the observed warming (e.g., lower tropospheric warming and stratospheric cooling) was also consistent with increases in GHG concentrations, but not other possible forcings. *Id.* at 867–952.

> GHGs contributed a global mean surface warming likely to be between 0.5°C and 1.3°C over the period 1951–2010, with the contributions from other anthropogenic forcings likely to be between –0.6°C and 0.1°C, from natural forcings likely to be between –0.1°C and 0.1°C, and from internal variability likely to be between –0.1°C and 0.1°C.[70]

Based on these estimates, AR5 concluded that "[i]t is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together."[71]

Since then, the warming trend has continued and a number of temperature-related records have been broken.[72] NCA4 found, with *very high confidence*, that: (i) global surface air temperature had increased by 1.8°F (~1°C) between 1901 and 2016, and (ii) "[m]any lines of evidence demonstrate that it is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century."[73] With regards to this attribution finding, USGCRP noted that there are "no convincing alternative explanations" for the observed warming in the past century.[74] USGCRP further found, with *high confidence*, that the likely range of human contribution to global mean temperature increase from 1951–2010 was 1.1° to 1.4°F (0.6° to 0.8°C) and that the likely contributions from natural forcing and internal variability to observed warming are minor.[75] There are a number of other recent studies which have reinforced and strengthened the evidentiary basis for human-induced warming. Analyses of global and regional warmth in 2014, 2015, 2016, and 2017 all found significant anthropogenic influence on record-breaking annual

70. *Id.* at 869.
71. *Id.* at 17.
72. Nineteen of the twenty hottest years on record have occurred since 2000 (with 1998 being the other hottest year), and 2016 was the hottest year on record with an average land and sea temperature that was 0.94°C above the 20th century average of 13.9°C. *See* NOAA, Climate Monitoring, https://www.ncdc.noaa.gov/climate-monitoring/global/globe/ytd/201911.
73. NCA4, *supra* note 7, at 13–14.
74. *Id.*
75. *Id.*

temperatures.[76] One noteworthy study compared observed temperatures in 2016 to annual global temperatures calculated in an ensemble of more than 24,000 years of CMIP5 simulations serving as a "control" for atmosphere (e.g., simulations in which greenhouse gases are kept at pre-industrial levels) and found that the observed 2016 temperatures were roughly 1.3°C higher than the historical average from 1881–1920, whereas the most extreme heat event in the control simulations was only 0.5°C above the historical average.[77] The scientists concluded that the record-breaking heat in 2016 could not have occurred in the absence of anthropogenic forcing on climate.[78]

iii. Oceans and Sea Level Rise

Just as the atmosphere has warmed, so too have the oceans. Two key detection findings in AR5 were that: (i) "[o]cean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (*high confidence*)";[79] and (ii) "[i]t is *virtually certain* that the upper ocean (0–700 m) warmed from 1971 to 2010 . . . and it *likely* warmed between the 1870s and 1971."[80] With regards to attribution, AR5 found that "[i]t is *very likely* that anthropogenic forcings have made a substantial contribution to increases in global upper ocean heat content (0–700 m) observed since the 1970s."[81]

NCA4, which contained more recent measurements of ocean temperature, found that total ocean heat content has increased by approximately $33.5 \pm 7.0 \times 10^{22}$ joules since 1960 and that average sea surface temperature (SST) has increased by about 1.3°F ± 0.1°F (0.7°C ± 0.08°C) per century from 1900 through 2016.[82] USGCRP noted that the effect of anthropogenic forcing on this warming

76. *Explaining Extreme Events of 2017 from a Climate Perspective*, 100 BULL. AM. METROLOGICAL SOC'Y (SPECIAL SUPPLEMENT) S1 (2019) [hereinafter BAMS 2017]; *Explaining Extreme Events of 2016 from a Climate Perspective*, 99 BULL. AM. METROLOGICAL SOC'Y (SPECIAL SUPPLEMENT) S1 (2018) [hereinafter BAMS 2016]; *Explaining Extreme Events of 2015 from a Climate Perspective*, 97 BULL. AM. METROLOGICAL SOC'Y (SPECIAL SUPPLEMENT) S1 (2016) [hereinafter BAMS 2015]; *Explaining Extreme Events of 2014 from a Climate Perspective*, 96 BULL. AM. METROLOGICAL SOC'Y (SPECIAL SUPPLEMENT) S1 (2015) [hereinafter BAMS 2014].

77. BAMS 2016, *supra* note 76, at S11–14.

78. *Id.*

79. IPCC AR5 WGI, Summary for Policy Makers, supra note 25, at 8.

80. *Id.*

81. *Id.* at 17.

82. NCA4, *supra* note 7, at 364–65.

trend was clear but did not attempt to quantify that effect, possibly due to uncertainties about the actual magnitude of ocean warming stemming from a lack of long-term data (particularly with respect to deep ocean warming).[83] A recent study on heat content in the upper 2000 meters of the ocean found ocean warming approximately 40–50% faster than what was reported in the IPCC AR5 report.[84]

The increase in ocean heat content has been accompanied by observed increases in sea levels (and rates of sea level rise) since the 1800s. The observational record shows that, between 1901 and 2010, global mean sea level rose by approximately 0.19 meters (~7.5 inches).[85] AR5 found with *high confidence* that the rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia, and that sea level rise has been accelerating quite substantially during this time period (with the most rapid rate of rise occurring since 1993).[86] The primary drivers of rising sea levels to date are thermal expansion of the ocean (caused by increases in ocean heat content) and glacier mass loss. AR5 found *high confidence* in anthropogenic influence on these two drivers in the past half-century, which supported its conclusion that "[i]t is very likely that there is a substantial anthropogenic contribution to the global mean sea level rise since the 1970s."[87] NCA4 contained similar findings.[88]

iv. Cryosphere: Sea Ice, Glaciers, Permafrost, and Snowpack

The observational record has shown a substantial decline in northern hemisphere sea ice, terrestrial glaciers, and snowpack in the past century.[89] But there is considerable geographic variation in the magnitude and rate of the decline, as not all areas are warming at the same rate, and there has actually been a small

83. *Id.* at 366, 367, 381.

84. Lijing Cheng et al., *How Fast Are the Oceans Warming?*, 363 SCIENCE 128 (2019).

85. IPCC AR5 WGI, Summary for Policy Makers, *supra* note 25, at 11.

86. *Id.* For example, AR5 found that it is "*very likely* that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm yr^{-1} between 1901 and 2010, 2.0 [1.7 to 2.3] mm yr^{-1} between 1971 and 2010, and 3.2 [2.8 to 3.6] mm yr^{-1} between 1993 and 2010." *Id.*

87. *Id.* at 19.

88. NCA4, *supra* note 7, at 333 (finding that GMSL had risen by approximately 7–8 inches since 1900, and that human forcings had made a "substantial contribution" (*high confidence)* to observed sea level rise).

89. IPCC AR4 WGI, *supra* note 25, at 319–20; NCA4, *supra* note 7, at 303.

observed increase in Antarctic sea ice,[90] which is not fully understood.[91] Setting aside that uncertainty, one clear finding of AR5 was that there are "multiple lines of evidence [which] support very substantial Arctic warming since the mid-20th century."[92] There has also been a "considerable reduction in permafrost thickness and areal extent" in certain northern regions observed over the period 1975 to 2005.[93]

AR5 concluded that anthropogenic influences "very likely contributed to Arctic sea ice loss since 1979 . . . [,] likely contributed to the retreat of glaciers since the 1960s and the increased surface mass of the Greenland ice sheet since 1993 [,] . . . [and] likely [contributed] to observed reductions in Northern Hemisphere spring snow cover since 1970."[94] Similarly, NCA4 found with *high confidence* that it is very likely that human activities have contributed to sea ice loss, glacier mass loss, and northern hemisphere snow extent decline.[95] However, AR5 noted that there is *low confidence* in our scientific understanding of the extent to which anthropogenic influences have driven the aforementioned changes in the Antarctic, and both AR5 and NCA4 noted that there had actually been a small observed increase in Antarctic sea ice in the early 2000s, which would most likely be explained by localized natural variability.[96]

Research shows that these trends have continued and accelerated since AR5 was published. One recent study found that the

90. At least through approximately the middle of the 2010s, at which point a decline appears to have commenced. Claire L. Parkinson, *A 40-y Record Reveals Gradual Antarctic Sea Ice Increases Followed by Decreases at Rates Far Exceeding the Rates Seen in the Arctic*, 116 PROC. NAT'L ACAD. OF SCI. 14414, 14414–23 (2019).

91. Proposed explanations for the increase have included freshening of the waters near Antarctica (thereby facilitating sea ice formation) such as: Richard Bintanja et al., *The Effect of Increased Fresh Water from Antarctic Ice Shelves on Future Trends in Antarctic Sea Ice,* 56 ANNALS OF GLACIOLOGY 120 (2015); decreasing stratospheric ozone (inducing local cooling through changes in atmospheric circulation); and natural variability, John Turner et al., *Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent*, 36 GEOPHYSICAL RES. LETTERS 1 (2009).

92. IPCC AR5 WGI, Summary for Policy Makers, *supra* note 25, at 9.

93. *Id.*

94. *Id.* at 19.

95. NCA4, *supra* note 7, at 333. *See also* Noah Diffenbaugh et al., *Quantifying the Influence of Global Warming on Unprecendented Extreme Climate Events,* 114 PROC. NAT'L ACAD. OF SCI 4881 (2017), (finding "extremely high statistical confidence that anthropogenic forcing increased the probability of record-low Arctic sea ice extent").

96. IPCC AR5 WGI, Summary for Policy Makers, *supra* note 25, at 19; NCA4, *supra* note 7, at 39, ch. 11.

Greenland Ice Sheet is melting much faster than previously believed: the pace of ice melt has accelerated four-fold since 2003, with Greenland losing approximately 280 billion tons of ice per year between 2002 and 2016—enough to raise the worldwide sea level by 0.03 inches annually.[97]

v. Hydrologic Cycle and Precipitation

Ascertaining the effect of anthropogenic forcings on the hydrologic cycle and precipitation is one of the most challenging areas of climate change attribution. Part of the challenge is detecting change—in some regions spatial gradients of precipitation are large, while historical rainfall records are incomplete and contain mixed findings about the extent to which precipitation patterns have (or have not) changed since the early 1900s. Precipitation is also characterized by large natural variability across a range of timescales ranging from the intra-annual to the centennial. The detection findings in AR5 are therefore mixed: AR5 notes that there is high confidence that average precipitation in mid-latitude land areas has increased since 1951.[98] However, there is only medium confidence in precipitation change averaged over global land areas since 1951, and low confidence in precipitation change prior to 1951.[99]

With respect to attribution, AR5 found that anthropogenic forcings had likely accelerated the hydrologic cycle, primarily through increases in temperature which can induce more rapid evaporation and support heavier rain events. However, the effect on annual mean regional precipitation was unclear. Specifically, AR5 found that:

> It is *likely* that anthropogenic influences have affected the global water cycle since 1960. Anthropogenic influences have contributed to observed increases in atmospheric moisture content in the atmosphere (*medium confidence*), to global-scale changes in

97. Michael Bevis, *Accelerating Changes in Ice Mass Within Greenland, and the Ice Sheet's Sensitivity to Atmospheric Forcing,* 116 PROC. NAT'L ACAD. OF SCI 1934, 1934 (2019).

98. IPCC AR5 WGI, Summary for Policy Makers, *supra* note 25, at 4.

99. *Id.* at 5, 40. A recent paper that integrated climate models, observations, and reconstructions of climate over the past 1000 years detected an elevated risk of hydroclimatic drought (a blend of precipitation deficit and greater evaporation potential associated with warming) consistent with anthropogenic activities as early as the first half of the 20th century. Kate Marvel et al., *Twentieth-Century Hydroclimate Changes Consistent with Human Influence*, 569 NATURE 59 (2019).

> precipitation patterns over land (*medium confidence),* to intensification of heavy precipitation over land regions where data are sufficient (*medium confidence*), and to changes in surface and sub-surface ocean salinity (*very likely*).[100]

The changes in surface and subsurface ocean salinity are noted here due to the link between precipitation and salinity: the observational record shows that regions of high salinity (where evaporation is prevalent) have become more saline, whereas regions of low salinity (where precipitation is prevalent) have become fresher since the 1950s, and these regional trends provide "indirect evidence that evaporation and precipitation over the oceans have changed."[101]

NCA4 also contained mixed findings about the effect of rising GHG concentrations and temperatures on global precipitation patterns. NCA4 noted that there had been a modest rise in annual average precipitation across global land areas, but that this increase could not be deemed statistically significant due to a lack of data coverage in early rainfall records.[102] However, NCA4 did note that there had been an observed increase in arctic precipitation of approximately 5 percent since the 1950s, which had been detected and attributed to human activities.[103]

2. Extreme Event Attribution

Extreme event attribution is a branch of climate change attribution that seeks to understand how human-induced changes in the global climate system are affecting the frequency, severity, and other characteristics of extreme events, such as abnormally hot days, heat waves, tropical cyclones, abnormally heavy rainfall events, and meteorological droughts.[104] This can be contrasted with the

100. IPCC AR5 WGI, Summary for Policy Makers, *supra* note 25, at 17 (emphasis in original).

101. *Id.* at 8.

102. NCA4, *supra* note 7, at 46.

103. *Id.* at 47 (citing Seung-Ki Min et al., *Human-Induced Arctic Moistening*, 320 SCIENCE 518 (2008)).

104. Meteorological drought is defined based on climate variables, especially precipitation and temperature (and to a lesser extent solar radiation at the surface, wind, and atmospheric humidity). Hydrological drought, in contrast, is defined by shortages of available freshwater resources, such as reservoirs, groundwater, and rivers/streams. Hydrological drought, in contrast to meteorological drought, is thus linked more closely to freshwater usage and freshwater needs.

climate change attribution research described above, which focuses on changes in long-term mean variables rather than changes in extremes.

Since 2011, the Bulletin of the American Meteorological Society (BAMS) has been publishing annual reports on *Explaining Extreme Events from a Climate Perspective*.[105] The 2016 and 2017 BAMS reports both contained studies finding that certain extreme events could not have been possible in a pre-industrial climate, all of which were heat-related events.[106] Below, we summarize some of the methods used in this research and the confidence with which scientists have been able to attribute different types of extreme events to climate change.

a. Methods and Parameters

Extreme event attribution is rapidly advancing due to improved understanding of extreme events, improved modeling (including standardized sets of simulations that can be used by a broad research community), lengthening observational datasets and re-analyses (blends of observations and models), some of which now incorporate paleoclimate data like tree rings to develop pre-observational historical reconstructions,[107] more robust remote sensing data sets, and new analytical techniques.[108] Climate and weather models, in particular, are indispensable to most event attribution studies.[109] But statistical analysis can also be used in lieu of, or as a supplement to, models for locations with high quality observational records.[110]

105. *Explaining Extreme Events from a Climate Perspective,* BULL. AM. METEOROLOGICAL SOC'Y, https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective/ [https://perma.cc/7P25-68HT] (last visited Nov. 17, 2019).

106. *Id. See also* BAMS 2016, *supra* note 76; BAMS 2017, *supra* note 76.

107. *E.g.*, Marvel et al., *supra* note 99.

108. NAT'L ACAD. OF SCI., ENG'G AND MED., ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE 1 (2016) [hereinafter NAS 2016].

109. *Id.* at 44.

110. *See, e.g.*, IPCC AR5 WGI, *supra* note 25; Stefan Rahmstorf & Dim Coumou, *Increase of Extreme Events in a Warming World*, 108 PROC. NAT'L ACAD. OF SCI. 17905 (2011); Geert Jan van Oldenborgh, *How Unusual Was Autumn 2006 in Europe?*, 3 CLIMATE PAST 659 (2007); R. Vautard et al., *Extreme Fall 2014 Precipitation in the Cevenees Mountains, in* BAMS 2014, *supra* note 76, at S56; Geert Jan van Oldenborgh et al., *Climate Change Increases the Probability of Heavy Rains Like Those of Storm Desmond in the UK—An Event Attribution Study in Near-Real Time,* 12 HYDRO. EARTH SYST. SCI. DISCUSSIONS 13197 (2015).

Generally speaking, attribution of extremes is more challenging than attribution of means for a variety of reasons, including: 1) the local nature and short duration of many extremes (which makes them difficult to model given the coarse resolution of climate models); 2) the relative rarity of extreme events at a given location (which makes it difficult to detect and attribute a climate change "signal" amidst the large "noise" of natural variability); and 3) the cause-and-effect chains for extremes are often highly nonlinear and may include instantaneous and delayed effects.[111] There are also some modeling challenges that are particularly relevant for extreme event attribution. Christiansen (2015) notes models may be too Gaussian in their extreme events (that is, they don't produce enough of them). Furthermore, skewness—a statistical measure that is sensitive to the tails of the distribution—may vary by season. Scientists have devised statistical approaches to avoid the problems and limitations associated with climate models but all rely on simplifying assumptions.[112] Statistical approaches also tend to make the potentially faulty assumption that historical relationships will persist as the climate changes further.[113] Nonetheless, for many

111. Sebastian Sippel et al., *Warm Winter, Wet Spring, and an Extreme Response to Ecosystem Functioning in the Iberian Peninsula*, *in* BAMS 2016, *supra* note 76, at S80 (citing D.A. Frank et al., *Effects of Climate Extremes on the Terrestrial Carbon Cycle: Concepts, Processes, and Potential Future Impacts*, 21 GLOBAL CHANGE BIOLOGY 2861 (2015) and J.A. Arnone et al., *Prolonged Suppression of Ecosystem Carbon Dioxide Uptake After an Anomalously Warm Year*, 455 NATURE 383 (2008)).

112. For example, a study may assume that climate change can be represented by a polynomial trend and that any residual represents natural variability.

113. NAS 2016, *supra* note 108; Bo Christiansen, *The Role of the Selection Problem and Non-Guassianity in Attribution of Single Events to Climate Change*, 28 J. CLIMATE 9873 (2015). The above is one example of a much broader collection of approaches to addressing climate model limitations. Two other examples include: (1) Hannart proposed using (observed) data assimilation techniques to go beyond climate model ensembles (Hannart et al., *supra* note 51); (2) Numerous authors used optimal fingerprinting techniques (Gabriel Hegerl & Frank Zwiers, *Use of Models in Detection and Attribution of Climate Change*, 2 WIRES CLIMATE CHANGE 570 (2011); Nikolaos Christadis & Peter A. Stott, *Changes in the Geospatial Height at 500 hPa Under the Influence of External Climatic Forcings*, 42 GEOPHYSICAL RES. LETTERS 10798 (2015)) to develop approaches tailored to specific climate models. Based on some historical measure of skill by region and extreme event type, individual models can then be included or rejected in analyses (Andrew D. King et al., *The Timing of Anthropogenic Emergence in Simulated Climate Extremes*, 10 ENVTL. RES. LETTERS 1 (2015)). While such approaches offer advances relative to simple bias correction or using climate model output directly, there remains the possibility that (1) the "winning models" miss key processes/succeed for the wrong reasons, and (2) that they may miss emerging behavior as the planet warms. In both instances, prior strong performance by an individual model might not be indicative of skill in the emerging climate.

variables and locations, extreme event studies can generate reasonably reliable results.

The results of extreme event studies are sensitive to how the research question is framed,[114] and what methodological approaches and datasets are used. Studies may focus on a class of events, such as the 2017 Atlantic hurricane season, or an individual event. This second research area, sometimes called *single-event attribution*, is growing fast, and there are now hundreds of studies seeking to identify the "human fingerprint" on major storms, floods, heat waves, and other events.[115]

One critical framing question is how to define the "extreme event" (or event class) for the purposes of the study. This involves defining physical thresholds for what constitutes an "extreme" and determining the appropriate timeframe and spatial scale of the study, all of which have implications for the results of the study. For example, if in analyzing a heat extreme scientists select as their temperature threshold the maximum temperature achieved, and focus their analysis on the location that reached the highest temperatures during the heat event, the event may appear more exceptional, and the study less broadly relevant, than if the temperature threshold and spatial scale were selected in a more generic way. More fundamentally, there are often multiple metrics that could be used to define an extreme event. For example, a heat wave could be defined based on maximum temperature over the course of the heat wave, heat wave duration, a combination of temperature and moisture in the air, or atmospheric circulation associated with the event. Along similar lines, scientists may tend to study those events where attribution statements are easiest to make and/or where data availability and societal interest are high. These are just a few examples of how event framing can introduce selection bias into an attribution study, thus compromising the study results. Fortunately, selection bias is not an insurmountable obstacle: efforts are underway to standardize how extreme events are defined and selected for analysis, and this would have the

114. Framing includes how the event is defined, what conditioning is included, and how the results are presented (frequency vs. intensity, FAR vs. RR, etc.). NAS 2016, *supra* note 108, at 37.

115. *See, e.g.*, WORLD WEATHER ATTRIBUTION PROJECT, https://www.worldweatherattribution.org/ [https://perma.cc/5US8-M5ST] (last visited Dec. 29, 2019).

added benefit of facilitating more systematic comparison between extreme event studies.[116]

Scientists also have different options for how to go about analyzing the effect of anthropogenic climate change on the event. There are two approaches that dominate extreme event attribution studies.[117] The first is a "risk-based" approach, which focuses on the extent to which climate change has increased the probability (or risk) of an extreme event threshold (such as temperatures of 95°F) being crossed. The second is a "storyline" approach, which focuses on how a variety of factors, including climate change, have affected the characteristics and magnitude of an individual extreme event in its entirety. These approaches both have benefits and drawbacks, as described below.

The risk-based approach to extreme event attribution involves evaluating the extent to which human influence on climate has changed the probability of occurrence of an event at or below a particular threshold (e.g., a heavy rain event of five inches or less).[118] One key concept in such research is the "fraction of attributable risk" (FAR), which can be defined as the relative risk (or risk ratio)[119] of an extreme event or class of events occurring with and without anthropogenic climate change. The risk-based approach typically involves the use of two or more simulations from

116. NAS 2016, *supra* note 108, at 15.

117. The binary classification of risk-based vs. storyline approaches in the main text obscures some other approaches in the literature. As one example, Mann et al. suggested a modification to traditional frequentist statistical inference approach, that builds in prior physical understanding and updates based on experience. Michael E. Mann et al., *Assessing Climate Change Impacts on Extreme Weather Events: The Case for an Alternative (Bayesian) Approach*, 144 CLIMATIC CHANGE 131 (2017). Mann et al. equate it to the conditional storylines approach (for example: surface air temperature increase means more extreme temperatures, and means more moisture in the air), but goes on to propose something quite different. Mann et al. propose to use our full knowledge and expectations (through Bayesian statistics) rather than overweighting avoidance of type 1 errors (claiming a relationship where none exists). Mann et al. note that fear of type one error yields underestimates of risk and of human contributions to extremes (citing Stefan Rahmstorf et al., *Recent Climate Observations Compared to Projections*, 316 SCIENCE 709 (2007)). Mann et al. note that such a precautionary approach to risk is common in other fields where 'do no harm' prevails (citing Gerd Gigerenzer & Adrian Edwards, *Simple Tools for Understanding Risks: from Innumeracy to Insight*, 327 BRIT. MED. J. 741 (2003) (discussing this approach in the context of pharmaceuticals)). So, he says you get more accurate results and *additionally*, from a risk management and ethical perspective, more policy sound results.

118. Myles Allen, *Liability for Climate Change*, 421 NATURE 891, 891 (2003); Hannart et al., *supra* note 51.

119. Risk ratio/relative risk = the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group.

a climate model or models which differ in that 1) one simulation is meant to represent the "world that is"—that is with the greenhouse gas concentrations (and sometimes other forcings and changes in boundary conditions like a warming ocean as well) as they have evolved since an earlier reference period, and 2) the other simulation reflects a "counterfactual world" without anthropogenic forcing. Because climate models generally cannot reproduce the observed statistics of the extreme event in question, a corresponding percentile threshold is often used. For example, if a location experiences a five-inch rainfall event, and that is estimated based on observed data to be a once per year event, the precipitation threshold amount in the model that occurs once per year is used for the model comparisons. In mathematical terms:

$$FAR = 1 - P0/P1$$

Where P1 equals the probability of a climatic event (such as a heat wave) occurring in the presence of anthropogenic forcing of the climate system, and P0 equals the probability of the event occurring if the anthropogenic forcing were not present. If FAR equals zero, it means that anthropogenic climate change had no effect on the probability of the event occurring; if FAR equals one, it means that the event could not have happened in the absence of anthropogenic climate change; if FAR equals 0.5, it means that anthropogenic climate change doubled the probability of the event occurring. In multi-event studies, a FAR of 0.5 can be interpreted as meaning that half of the events would not have happened in a world without anthropogenic climate change.

This approach was pioneered by Myles Allen in a 2003 study in which he introduced the concept of FAR as a potential basis for liability for climate damages.[120] Many other studies have since replicated Allen's approach, estimating the FAR for a range of extreme events including heat waves, droughts, and floods. While the term FAR is almost exclusively used in extreme event attribution, probabilistic analysis is prevalent across all forms of attribution,[121] and the concept of "attributable risk" can in

120. Allen, *supra* note 118.

121. The prevalence of probabilistic analysis in both climate change and impact attribution is evident in the IPCC's frequent use of terms such as "likely" and "very likely" when describing human influence on observed changes and impacts.

principle be applied to both mean changes in climate[122] and a variety of climate change impacts. Indeed, the methodology derives from common approaches used in public health and other risk-focused research.[123] The advantages of this approach are that it is relatively well-established, understood, and accepted by the scientific community,[124] and it provides quantitative (probabilistic) findings similar to the sort of epistemological and environmental data that is often dealt with by policy-makers, planners, and courts. Drawbacks include: 1) overreliance on climate models, which as noted earlier, may not be able to simulate some types of extremes with fidelity in a baseline climate, and could have blind spots with respect to how climate change may be modifying key processes influencing the extreme event, and 2) susceptibility to Type II errors (i.e., false negatives) where the signal-to-noise ratio for an event is small due to large internal variability of the atmosphere, which is often the case for dynamically-driven events such as extreme precipitation and storms especially.[125] As such, it can

122. *See, e.g.*, Thomas Knutson et al., *CMIP5 Model-Based Assessment of Anthropogenic Influence on Record Global Warmth During 2016, in* BAMS 2016, *supra* note 76, at S13.

123. The concept of "attributable risk" actually originated in epidemiological studies (e.g., studies seeking to identify the extent to which smoking increases the risk of lung cancer) and is therefore well-suited for evaluating health-related risks. Some efforts have been made to quantify "attributable risk" for climate change-related health impacts, but most of these studies are forward-looking, and there is only a small body of research seeking to determine the attributable risk of observed public health impacts. There is still a strong need for more quantitative analysis on this topic. *See infra* Section II(B)(3); Kristie L. Ebi et al., *Monitoring and Evaluation Indicators for Climate Change-Related Health Impacts, Risks, Adaptation, and Resilience*, 15 INT'L. J. ENVTL. RES. PUB. HEALTH 1943 (2018) (discussing the need to develop quantitative indicators of climate change-related health risks); Wei W. Xun et al., *Climate Change Epidemiology: Methodological Challenges,* 55 INT'L. J. PUB. HEALTH 85 (2010) (discussing challenges in attributing epidemiological risks to climate change); Maud M.T.E. Huynen & Pim Martens, *Climate Change Effects on Heat- and Cold-Related Mortality in the Netherlands: A Scenario-Based Integrated Environmental Health Impact Assessment*, 12 INT'L. J. ENVTL. RES. PUB. HEALTH 13295 (2015) (quantifying the population attributable fractions (PAF) of mortality due to heat and cold, but projecting future impacts rather than attributing current impacts); S.J. Yoon et al., *Measuring the Burden of Disease Due to Climate Change and Developing a Forecast Model in South Korea*, 128 PUB. HEALTH 725 (2014) (quantifying influence of climate change on disease burden in South Korea).

124. *See* NAS 2016, *supra* note 108, at 3.

125. Kevin Trenberth et al., *Attribution of Extreme Climate Events*, 5 NATURE CLIMATE CHANGE 725 (2015).

underestimate the extent to which anthropogenic influence has increased the probability of an event.[126]

Some probabilistic approaches have adopted conditional risk-based analyses, both to simplify the modeling and to control for factors other than anthropogenic effects (such as natural variability, as discussed above).[127] Conditional analyses can in some respects be thought of as a logical outgrowth of the tension between risk based and storyline conceptualizations,[128] since they attempt to isolate the component of extreme events due to anthropogenic warming by treating other components as a control. For example, natural variability of the ocean surface could be treated as a control through a climate model experiment that used the same observed sea surface temperature *patterns* (on the assumption that patterns are due to natural variability) to drive both the counterfactual and anthropogenic forcing simulations, while universally increasing the SSTs by the amount assumed to correspond to anthropogenic forcing. By comparing the results, scientists can largely avoid the criticism that natural variability in ocean temperatures may have led to differences between the two sets of results. However, one price paid is that by simplifying the experiment, full probabilistic attribution is no longer possible, since the experiment was designed so as to ignore the question of how sea surface temperature patterns may be impacted by anthropogenic forcing. Also unaddressed is the possibility that the estimated magnitude of SST warming assumed with the anthropogenic forcing in the experimental design could be wrong. As models become more interactive and experimental designs grow more complex, the problem of what parts to condition become more and more vexing. Harrington summarized conditioning this way:

> More conditioning on the observations of the event will result in an attribution statement with higher confidence (as some possible sources of uncertainty will have been eliminated (Shepherd 2016)), but it will have less relevance to other extreme events which may occur in the future (Otto et al. 2016), and may only quantify the

126. FAR is not well defined when the baseline risk is very low; it also is not designed to be applied to situations with decreasing risk. NAS 2016 , *supra* note 108, at 28. Furthermore, when there are multiple causes, FAR can exceed 1.

127. *See supra* Section II(B)(1).

128. For further discussion of the storyline approach, see *infra* page 32.

> human influence on one part of a causal chain of physical phenomena contributing to the severity of a given event. From the perspective of an in-depth attribution study, multiple perspectives using varying levels of conditioning may therefore be complimentary.[129]

The "storyline" approach to extreme event attribution provides an alternative method for evaluating how climate change affected some or all of the components that come together to form an individual extreme event.[130] This approach is conditional in the sense that it takes the unique extreme event as given; rather than asking whether it could have happened without anthropogenic forcing, it asks how anthropogenic forcing may have modified the given event.[131]

The storyline approach was first introduced by Trenberth et al. (2015) as an alternative to the risk-based approach. The approach begins with the idea that some aspects of climate change are better understood than others, with warming temperature and thermodynamics emerging as first order aspects of climate change that are relatively straightforward to model and understand. Proponents of the approach have emphasized that, by contrast, changes in dynamics, or motion, with climate change are poorly understood and poorly simulated by models.[132] The storyline approach, focusing only on components that are well understood, like thermodynamics, allows for higher confidence statements about a portion of the event that science understands well, albeit it at the expense of having to forsake complete, quantitative statements.[133] A typical finding from a storyline approach might be

129. Luke James Harrington, *Novel Approaches to Quantify the Emergence of Anthropogenic Climate Change* (2017), (unpublished Ph.D. dissertation, Victoria University of Wellington) (on file with New Zealand Climate Change Research Institute School of Geography, Environment and Earth Sciences).

130. The storyline approach was first introduced by Kevin Trenberth. *See* Trenberth et al., *supra* note 125, at 726.

131. Theodore G. Shepherd, *A Common Framework for Approaches to Extreme Event Attribution*, 2 CURRENT CLIMATE CHANGE REP. 28, 28 (2016).

132. The National Academies explained: "Changes in atmospheric circulation and dynamics are generally less directly controlled by temperature, less robustly simulated by climate models, and less well understood." NAS 2016, *supra* note 108, at 6.

133. The reader may note similarities between conditional probabilistic attribution and the storylines approach. Conditional attribution starts by saying 'given this . . .'. The "given" in this context is often sea surface temperatures or sea ice extent, but it can also be a certain type of atmospheric circulation. The idea is to move part of the conditions, often the most vexing part, out of the attribution question. This approach still leaves the question open

"warming of the upper ocean and atmosphere associated with climate change enabled more rainfall during event Y than otherwise would have been experienced." In some studies, quantitative statements are included as well based on certain limited assumptions. In the above example, it might be stated that the warming of the upper ocean and atmosphere due to climate change—the thermodynamics—were responsible for an X percent increase in rainfall. Critically though, any quantitative statements, rather than being comprehensive, are linked to specific aspects of the climate system identified by the authors, such as water temperatures in the example above. Furthermore, most storyline approaches do not endeavor to assess what percentage of the driver—ocean temperature in the example above is due to human activity.

As with the probabilistic or risk based approach, several criticisms have been raised of the storyline approach.[134] First, focusing on a single event in its entirety (as opposed to the risk-based approach, in which events that are defined solely based on their exceedance of a threshold such as 95°F, or air pressure at a given height) and emphasizing changes across only a portion of the event drivers (e.g., focusing on thermodynamics rather than dynamics) limits the utility of the storylines approach for traditional policy and legal applications. Since each event is treated as unique, the applications for a class of events is unclear, and emphasis on a portion of the event's drivers, often in a qualitative way, immediately begs the question of how to address remaining drivers or summarize the event in toto. Second, the storyline approach has been criticized as oversimplistic due to the compartmentalization of an event into discrete components. More specifically the basic premise that within the context of climate change thermodynamics are well understood, and dynamics are not (or are unlikely to change in important ways for extreme events), has been challenged, with some arguing that there is a smooth gradient of understanding across system components such as thermodynamics

though of whether anthropogenic warming has impacted the part being taken as given. The storyline approach takes a full, specific event as the given; tries to initially identify all aspects and drivers; but then focuses on backing out how some of the better understood aspects of climate change—generally the thermodynamics, may have impacted the event magnitude.

134. Friederike E. Otto et al., *The Attribution Question*, 6 NATURE CLIMATE CHANGE 813 (2016).

and dynamics.[135] Furthermore, thermodynamics and dynamics interact. For example, a thermodynamic change, such as warming of the upper ocean, induces changes in the dynamics of atmospheric circulation such as rising air, which can feed back on thermodynamics, for example by changing cloud cover and thus solar radiation received at the surface. Neglecting dynamics thus inevitably misses ways that thermodynamics can be impacted by dynamics, thus rendering the thermodynamics analysis incomplete.[136] Another potential drawback of this approach is that it generates more qualitative findings that may be less useful for certain applications than the quantitative findings of the risk-based approach.[137]

While there is some debate about the relative merits of these two approaches, the reality is that they are complementary—they each provide different insights on the effect of anthropogenic climate change on event characteristics, and one approach can be used to fill gaps where the other is unsuitable. For example, the probabilistic/risk-based approach may be more justifiable for analyzing all events below a threshold, for a class of events that are

135. For example, Mann et al. (2017) notes that dynamical changes with warming are starting to come into focus: more specifically, a growing body of work based on observations and simple models supports the idea that the latitudinal pattern of mean temperature changes (including Arctic amplification) may support changes in atmospheric dynamics that supports wave resonance and 'stuck' weather, which enhances the magnitude and duration of extremes. It should be noted that global climate models generally do not reproduce this pattern of wave resonance and 'stuck' weather with warming. Michael E. Mann et al., *Influence of Anthropogenic Climate Change on Planetary Wave Resonance and Extreme Weather Events*, 7 SCI. REPORTS 45242 (2017).

136. Otto shows how the dynamics and thermodynamics counteracted each other in 2013 German floods. *See* Otto et al., *supra* note 134, at 815. Similarly, a study in Western Australia found dynamics/circulation changes that favor less rain, but thermodynamic (specifically sea surface temperature) changes that favor increase in rain. Thomas L. Delworth & Fanrong Zeng, *Regional Rainfall Decline in Australia Attributed to Anthropogenic Greenhouse Gases and Ozone Levels*, 7 NATURE GEOSCIENCE 583 (2014).

137. For example, the quantitative findings from risk-based studies may be more suitable to answering questions about apportioning liability for climate change. A related criticism is that individual extreme events are complicated, and the storyline approach, through its lack of a clear methodology, opens doors to claims of cherrypicking. For example, Trenberth et al. note that during the "Snowmaggendon event" unusually high sea surface temperatures led to more moisture being available. Trenberth et al., *supra* note 125, at 727. The authors are silent on other drivers of snowfall amount, such as storm location and availability of cold air. In this instance, the approach is arguably justified given the "thermodynamic" links between sea surface temperature and warming, but especially in the hands of less knowledgeable researchers, the lack of a clear, replicable methodology may open the door to perceptions of cherrypicking of event components.

relatively well simulated by climate models (e.g., 99% temperature extremes), whereas the storylines approach may be more appropriate for complex, iconic, multivariate events such as Hurricane Sandy, which combine everything from extreme storm surge and snowfall to high winds.[138] Granted, even with both approaches there is still a fair amount of uncertainty about the human fingerprint on certain events and certain event classes.[139] This is evident from the fact that the risk-based and storyline approaches can produce very different findings about the magnitude of the human influence on certain events, as highlighted in our discussion of specific event studies below.[140]

A recent development in this field is the emergence of and growing focus on "rapid" and "advance" (or "predictive") event attribution. The World Weather Attribution (WWA) project, founded in 2014, is at the forefront of these efforts: it conducts "real-time" (i.e., rapid) attribution analysis of extreme weather events that happen around the world.[141] To accomplish this, WWA and other like entities use seasonal forecasts rather than observations to simulate extreme weather events under current climate conditions before the events actually occur. The goals of this approach are twofold: first, to demonstrate the feasibility of using forecast for reliable attribution findings, and second, to make it possible to issue attribution findings for extreme weather events as they occur.[142] This second function can help facilitate engagement with the media, policy-makers, and the public while events are still fresh in everyone's mind. However, some scientific rigor may be lost when research is conducted with such alacrity. For example, there may be less opportunity to test the model's ability to simulate the actual event, and there may be little or no time for traditional peer-review. Nevertheless, as attribution research continues to mature, and standardization of experiments

138. Elisabeth Lloyd & Naomi Oreskes, *Climate Change Attribution: When Is It Appropriate to Accept New Methods?,* 6 EARTH'S FUTURE 311 (2018).

139. To help address uncertainty, the National Academies has noted a need for more research on: (i) the role of natural variability in extreme events; (ii) the characterization of uncertainty; (iii) why it is that different approaches have yielded very different findings; (iv) what methods are used for event section; and (v) how the counterfactual (no anthropogenic climate change) world is framed. NAS 2016, *supra* note 108, at 12.

140. *See infra* section II(B)(2)(b).

141. WORLD WEATHER ATTRIBUTION PROJECT, *supra* note 115.

142. About World Weather Attribution, https://www.worldweatherattribution.org/about/ (last visited Jan. 14, 2020).

enables more multi-model evaluations, rapid—and even predictive—event attribution will grow in prominence and robustness.

b. Status of Research

IPCC AR5 summarized the status of observations on extreme events as follows:

> Changes in many extreme weather and climate events have been observed since about 1950. It is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. It is likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia. There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The frequency or intensity of heavy precipitation events has likely increased in North America and Europe. In other continents, confidence in changes in heavy precipitation events is at most medium.[143]

NCA4 contained similar findings.[144] With respect to attribution, both AR5 and NCA4 recognized that the evidence of human influence on extreme events varies depending on the event and, in many cases, is difficult to ascertain. Generally speaking, the confidence with which scientists have been able to attribute extreme events to climate change has been highest for events that are directly related to temperature.[145] Extreme events that are the result of more complex interactions between variables (e.g., drought) are more difficult to attribute. There is moderate confidence about extreme precipitation increases. While there is relatively low confidence about precipitation deficits alone in the context of drought, there is higher confidence in the combined impacts of higher temperature and precipitation on drought risk. For other classes of severe weather, such as tropical cyclones, mid-latitude storms, and smaller scale convective events and tornadoes, confidence is generally lower. However, these generalizations mask substantial nuance across space and time; for example, high temperature extremes at individual highly continental locations in

143. IPCC AR5 WGI, Summary for Policymakers, *supra* note 25, at 5.
144. NCA4, *supra* note 7, at 207–76.
145. NAS 2016, *supra* note 108, at 2.

the mid and high latitudes (where internal variability is large) may be difficult to attribute, and high water level extremes may be difficult to attribute in places where large storm surges are relatively frequent, rendering the sea level rise signature on coastal high water levels relatively less prominent.

Since AR5 was published in 2013, the world has seen a growing number of record-breaking extreme events and hundreds of new event attribution studies have been published. The majority of these studies deal with heat, precipitation, and storm-related impacts, but a growing number of studies are assessing more novel types of extremes—as one example, a recent study looked at "extreme winter sunshine" in the United Kingdom.[146] Notably, of the 146 studies published in the BAMS reports since 2011, approximately 70% have found that anthropogenic climate change was a significant driver of the event studied.[147] The 2016 and 2017 BAMS reports also contained several studies in which the authors concluded that the event *could not have happened* in the absence of anthropogenic climate change. Another meta-analysis of extreme event attribution studies, published in 2018, found that forty-one of fifty-nine papers published in 2016 and 2017 found a positive signal of climate change, and that thirty-two of forty-three papers published in 2018 found that climate change had increased the event's likelihood or intensity.[148] That meta-study also noted that the only four studies published in 2018 which found that climate change decreased the likelihood or intensity of the event all dealt with snow and/or cold temperatures.[149] With all this new research, the evidentiary basis for attributing extreme events to climate change is growing rapidly.

i. Extreme Heat

The core characteristics of extreme heat events (magnitude, frequency, and duration) are all highly sensitive to changes in mean temperatures at a global scale.[150] Thus, an increase in the

146. Nikolaos Christidis et al., *Human Contribution to the Record Sunshine of Winter 2014/15 in the United Kingdom*, *in* BAMS 2015, *supra* note 76, at 47.

147. *See* Stephanie C. Herring et al., *Abstract*, *in* BAMS 2016, *supra* note 76, at Sii.

148. RICHARD BLACK & RUSSEL BAUM, ENERGY & CLIMATE INTELLIGENCE UNIT, EVEN HEAVIER WEATHER 6 (2018).

149. *Id.*

150. Radley M. Horton et al., *A Review of Recent Advances in Research on Extreme Heat Events*, 2 CURRENT CLIMATE CHANGE REP. 242, 242 (2016).

magnitude, frequency, and duration of extreme temperature events is a direct and foreseeable consequence of a warming climate. Not surprisingly, confidence in attribution findings is generally greatest for extreme heat events, as compared with other types of extreme events.[151] NCA4 found, with *very high confidence*, that the frequency and intensity of extreme heat events are increasing in most continental regions around the world, consistent with the expected physical responses to a warming climate.[152]

One of the earliest extreme event attribution studies dealt with the European heat wave of 2003. Applying the risk-based approach, Stott et al. (2004) found that it was very likely (confidence level >90%) that human influence had at least doubled the risk of a heat wave of the sort experienced that summer.[153] Since then, scientists have developed a robust body of research linking unusually warm temperatures and heat waves to anthropogenic climate change.[154] One meta-analysis of unprecedented extremes on a global level found that:

> [H]istorical warming has increased the severity and probability of the hottest month and hottest day of the year at >80% of the available observational area. For the most protracted hot and dry events, the strongest and most widespread contributions of anthropogenic climate forcing occur in the tropics, including increases in probability of at least a factor of 4 for the hottest month and at least a factor of 2 for the driest year.[155]

The studies contained in recent BAMS reports further reinforce this conclusion. The BAMS reports covering 2014 through 2017

151. NAS 2016, *supra* note 108, at 7; *see* Stephanie C. Herring et al., *Introduction to Explaining Extreme Events of 2016 From a Climate Perspective*, *in* BAMS 2016, *supra* note 76, at S2.

152. NCA4, *supra* note 7, at 19.

153. Peter Stott et al., *Human Contribution to the European Heatwave of 2003,* 432 NATURE 610, 610 (2004).

154. IPCC AR5 WGI, Summary for Policymakers, *supra* note 25, at 19 ("There has been further strengthening of the evidence for human influence on temperature extremes since the SREX. It is now very likely that human influence has contributed to observed global scale changes in the frequency and intensity of daily temperature extremes since the mid-20th century, and likely that human influence has more than doubled the probability of occurrence of heat waves in some locations.").

155. Diffenbaugh et al., *supra* note 95, at 4881. The researchers noted that the framework they used in this study was capable of systematically evaluating the role of dynamic and thermodynamic factors such as atmospheric circulation patterns and atmospheric water vapor, lending much greater statistical confidence their findings.

contained a total of thirty-five studies examining anthropogenic influence on extreme heat (including terrestrial and marine heat), and thirty-three of those studies (91%) found that anthropogenic climate change had increased either the likelihood or the severity of the heat event.[156] Notably, there were several studies in the two most recent reports (from 2016 and 2017) which concluded that heat-related events would have been "virtually impossible" in the absence of anthropogenic influence on climate. One of these studies focused on record-breaking global annual *mean* surface temperatures in 2016,[157] while others focused on phenomena that more closely fit the definition of an "extreme" event, specifically: extreme heat in Asia,[158] and marine heat waves off the coast of Alaska[159] and Australia.[160] All three studies employed the risk-based approach and found that FAR equals one, meaning the event could not have happened without anthropogenic influence. The BAMS editors noted these findings were novel and significant for two reasons: (i) they show that the influence of anthropogenic climate change can, at some point, become sufficiently strong to cause an extreme event which is beyond the bounds of natural variability alone; and (ii) because of the small sample size of events shown in the report, it is possible that many other temperature-related extreme events from recent years also could not have occurred in the absence of anthropogenic climate change.[161]

Dozens of other studies have found that climate change very likely influenced the probability and/or magnitude of heat-related events around the world. One study focused on two heat waves in India and Pakistan in 2015 which are estimated to have caused approximately 3,200 deaths.[162] Looking at both heat and humidity (such compound assessments of multiple variables are becoming

156. BAMS 2014, *supra* note 76; BAMS 2015, *supra* note 76; BAMS 2016, *supra* note 76; BAMS 2017, *supra* note 76.

157. Thomas Knutson et al., *CMIP5 Model-Based Assessment of Anthropogenic Influence on Record Global Warmth During 2016, in* BAMS 2016, *supra* note 76, at S11.

158. Yukiko Imada et al., *Climate Change Increased the Likelihood of the 2016 Heat Extremes in Asia, in* BAMS 2016, *supra* note 76, at S97.

159. John Walsh et al., *The High Latitude Marine Heat Wave of 2016 and Its Impacts on Alaska, in* BAMS 2016, *supra* note 76, at S39.

160. S.E. Perkins-Kirkpatrick et al., *The Role of Natural Variability and Anthropogenic Climate Change in the 2017/18 Tasman Sea Marine Heatwave, in* BAMS 2017, *supra* note 76, at S105.

161. Herring et al., *supra* note 151, at S1.

162. Michael Wehner et al., *The Deadly Combination of Heat and Humidity in India and Pakistan in Summer 2015, in* BAMS 2015, *supra* note 76, at S81.

more common), the researchers found that anthropogenic forcing had substantially increased the likelihood of the observed heat indices (by approximately 800–100,000%).[163]

Another compound extremes study focused on heat and drought in Thailand, specifically examining the causal forcings behind a severe drought, which affected forty-one Thai provinces and caused an agricultural loss of approximately $500 million, and a corresponding heat wave which resulted in an estimated six-fold increase in heat stroke cases as well as extensive forest fires throughout the country.[164] There, researchers found that record temperatures could not have occurred without the influence of anthropogenic influence on climate, and that this increased the likelihood of low rainfall in the region.[165] A third study looking at anomalous Arctic warmth in the winter of 2016 concluded that it "most likely" would not have been possible without anthropogenic forcing (the FAR ranged from 0.96-0.99 across five observational datasets).[166]

While the above studies provide compelling evidence of human influence on extreme heat events, it is important to recognize that quantitative estimates of risk ratios can differ considerably depending on the method used in the research. This was one key finding from a study examining the role of anthropogenic warming in the 2015 central and eastern European heat waves.[167] There, researchers used a combination of statistical analysis of observational data and model simulations for attribution purposes. They found that both approaches provided "consistent evidence that human-induced climate change has contributed to the increase in the frequency and intensity of short-term heat waves and heat stress" in the region, but that risk ratio (or FAR) estimates at local scales differ considerably depending on the exact methodology applied.[168] It should be noted that the fact that more heat attribution studies rely on models than rely on observations

163. *Id.* at S85.

164. Nikolaos Christidis et al., *The Hot and Dry April of 2016 in Thailand*, *in* BAMS 2016, *supra* note 76, at S128.

165. *Id.*

166. Jonghun Kam et al., *CMIP5 Model-based Assessment of Anthropogenic Influence on Highly Anomalous*
Arctic Warmth During November–December 2016, *in* BAMS 2016, *supra* note 76, at S34, S36.

167. Sebastian Sippel et al., *The Role of Anthropogenic Warming in 2015 Central European Heat Waves*, *in* BAMS 2015, *supra* note 76, at S51.

168. *Id.* at S55.

does not indicate that models overestimate anthropogenic influence relative to observations. For example, Sippel and Otto, using a high resolution climate model simulation, found that observed upward trends in heat extremes were three times larger between 1901–2015 than the trend in the climate model driven by historical forcings, suggesting that using observations would have produced a change in relative risk that was three times larger than the model yielded.[169] Another study relying exclusively on statistical analysis of observations to examine the 2010 Russian heat wave found that the warming in the region observed since the 1960s had increased the risk of a heat wave of the magnitude observed in 2010 by a factor of approximately five, corresponding to a FAR of 0.8.[170]

ii. Drought

While drought is closely connected to increases in temperature, it is typically more challenging to isolate the effect of anthropogenic climate change on dryness and drought conditions because droughts are such highly complex meteorological events (with many factors affecting their probability, severity, and duration) and because large internal variability in precipitation makes it more difficult to identify a climate change signal.[171] Nonetheless, researchers have made significant advances in drought attribution in recent years. Of the twelve studies on drought and dryness that were included in the 2015, 2016, and 2017 BAMS reports, eleven (92%) found clear evidence of anthropogenic influence on the severity or probability of the observed event.[172]

One persistent finding is that it is easier to attribute the heat-related aspects of drought to anthropogenic activities than it is to attribute reductions in rainfall, due to the dynamic nature of the hydrologic cycle.[173] For example, a study of the 2014 drought in

169. *See id.* at S53–S55. As noted earlier, however, use of observations without models is somewhat fraught, for reasons including the difficultly of isolating natural variability in models and (in some cases) data limitations.

170. Rahmstorf & Coumou, supra note 110, at 17905.

171. In this section, we use the term "drought" to refer to meteorological drought—that is, drought brought about by dry weather patterns. Studies examining hydrologic drought—that is, drought brought about by low water levels—would more properly be classified as "impact attribution studies."

172. BAMS 2015, *supra* note 76; BAMS 2016, *supra* note 76; BAMS 2017, *supra* note 76.

173. *See, e.g.*, NCA4, *supra* note 7, at 22: "The human effect on recent major U.S. droughts is complicated. Little evidence is found for a human influence on observed

the Horn of Africa found no evidence of anthropogenic influence on the likelihood of low rainfall, but "clear signals in other drivers of drought" (namely, higher temperatures and increased net incoming radiation).[174] One assessment of observed "flash droughts"[175] in southern Africa found that these events had increased by 220% from 1961–2016, and that there had also been a decreasing trend in precipitation from 1948–2016, but also recognized that "simulations of surface air temperature change are much more reliable than those for soil moisture and precipitation."[176] A model based study which also focused on drought in southern Africa found that climate change likely increased the intensity of the 2015–2016 El Niño which in turn contributed to decreases in precipitation in the region.[177]

The numerous studies on the 2011–2017 California drought also reflect the complexity and dependency of results on methodological choices. Swain 2014 focused on geopotential heights (the heights of pressure surfaces above mean sea level) because droughts are associated with high atmospheric pressure and blockage of moisture-laden storms, and found that high heights were attributable to anthropogenic warming.[178] Funk 2014, focusing on warming of ocean temperatures off a portion of the US West coast, found that the ocean warming did not contribute to drought risk.[179] And Wang and Schubert found conflicting results: circulation anomalies associated with anthropogenic forcing did increase drought risk, but humidity increases associated with

precipitation deficits, but much evidence is found for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. (*High confidence*)".

174. T. R. Marthews et al., *The 2014 Drought in the Horn of Africa: Attribution of Meteorological Drivers*, *in* BAMS 2014, *supra* note 76, at S83; *see also* Eduardo S. P. R. Martins et al., *A Multimethod Attribution Analysis of the Prolonged Northeast Brazil Hydrometeorological Drought (2012–16)*, *in* BAMS 2016, *supra* note 76, at S65.

175. The term "flash drought" refers to a rapid-onset drought, typically caused by very dry and hot weather conditions.

176. Xing Yuan et al., *Anthropogenic Intensification of Southern African Flash Droughts as Exemplified by the 2015/16 Season*, *in* BAMS 2016, *supra* note 76, at S86.

177. Chris Funk et al., *Anthropogenic Enhancement of Moderate-to-Strong El Niño Events Likely Contributed to Drought and Poor Harvests in Southern Africa During 2016*, *in* BAMS 2016, *supra* note 76, at S91.

178. Daniel L. Swain et al., *The Extraordinary California Drought of 2013-2014: Character, Context, and the Role of Climate Change*, 95 BULL. AM. METEOROLOGICAL SOC'Y (SPECIAL SUPPLEMENT) S3, S7 (2014) [hereinafter BAMS 2013].

179. Chris Funk et al., *Examining the Contribution of the Observed Global Warming Trend to the California Droughts of 2012/13 and 2013/14*, *in* BAMS 2013, *supra* note 178, at S11.

anthropogenic warming reduced drought risk.[180] However, a more recent study found that anthropogenic warming *had* increased drought risk in California—specifically, that the precipitation deficits in California were more than twice as likely to yield drought years if they occurred when conditions were warm.[181]

iii. Heavy Precipitation

Both AR5 and NCA4 found clear evidence that extreme rainfall events are increasing around the world, and this is generally consistent with expected physical responses to a warming climate.[182] However, as noted above, the dynamic nature of extreme precipitation events—which can be very local and brief in nature, and thus characterized by large variability and difficult to model—can make it more difficult to attribute specific precipitation events to anthropogenic climate change than temperature extremes, particularly where scientists use the risk-based approach to attribution. In the BAMS reports published for 2014 through 2017, ten out of eighteen studies on heavy precipitation (56%) identified an anthropogenic influence on event frequency or magnitude.[183] But to the extent that studies have found a link to anthropogenic activities, some of the results have been quite striking.

One study of extreme rainfall in China in 2016 found that anthropogenic forcings, combined with the 2015–2016 strong El Niño cycle, had increased the risk of the rainfall event tenfold.[184] Other studies looking at extreme rainfall events in China have similarly found evidence of anthropogenic forcing on extreme

180. Hailan Wang & Siegfried Schubert, *Causes of the Extreme Dry Conditions Over California During Early 2013*, *in* BAMS 2013, *supra* note 178, at S7.

181. Noah Diffenbaugh et al., *Anthropogenic Warming Has Increased Drought Risk in California,* 112 PROC. NAT'L ACAD. SCI. 3931, 3931 (2015).

182. NCA4, *supra* note 7, at 19 ("The frequency and intensity of . . . heavy precipitation events are increasing in most continental regions of the world (*very high confidence*)"); IPCC AR5 WGI, Summary for Policymakers, *supra* note 25, at 7. With each additional degree Celsius of warming, the atmosphere is capable of holding an additional 7% more water vapor. Dim Coumou & Stefan Rahmstorf, *A Decade of Weather Extremes,* 2 NATURE CLIMATE CHANGE 491 (2012).

183. BAMS 2014, *supra* note 76; BAMS 2015, *supra* note 76; BAMS 2016, *supra* note 76; BAMS 2017, *supra* note 76.

184. Qiaohong Sun & Chiyuan Miao, *Extreme Rainfall (R20mm, RX5day) in Yangtze–Huai, China, in June–July 2016: The Role of ENSO and Anthropogenic Climate Change*, *in* BAMS 2016, *supra* note 76, at S102.

rainfall and flood events in that region.[185] Meredith et al. (2015) used a high-resolution regional climate model to assess how water temperature increases in the Black Sea affected a highly-local "convective" precipitation event.[186] They found a 300% increase in extreme precipitation associated with a non-linear transition in the stability of the atmosphere.[187] A lower resolution model would not be able to resolve this non-linear precipitation change associated with higher sea surface temperatures.[188]

As noted above, the "storyline" approach to attribution was developed in part to improve attribution for difficult to model events like extreme precipitation. Researchers used this approach to examine the effect of anthropogenic climate change on the 2013 floods in Boulder, Colorado, and found that anthropogenic drivers increased the magnitude of the rainfall for that week by approximately 30%.[189] The scientists also conducted a probabilistic analysis of potential impacts on flooding and found that this 30% increase in rainfall approximately doubled the likelihood of flood-inducing rainfall occurring during that event.[190] In contrast, researchers evaluating the Boulder floods under the risk-based framework found no evidence that anthropogenic climate change had increased the probability of the event occurring.[191] This underscores the sensitivity of results to methodological choices made in extreme event attribution.

185. Claire Burke et al., *Attribution of Extreme Rainfall in Southeast China During May 2015*, *in* BAMS 2015, *supra* note 76, at S92; Chunlüe Zhou et al., *Attribution of the July 2016 Extreme Precipitation Event Over China's Wuhang*, *in* BAMS 2016, *supra* note 76, at S107.

186. Edmund P. Meredith et al., *Evidence for Added Value of Convection-Permitting Models for Studying Changes in Extreme Precipitation*, 120 J. GEOPHYSICAL RES. ATMOSPHERE 12500, 12500 (2015).

187. *See* Edmund P. Meredith et al., *Crucial Role of Black Sea Warming in Amplifying the 2012 Krymsk Precipitation Extreme*, 8 NATURE GEOSCIENCE 615, 615 (2015). This increase was related to the change in temperature with height; warming water warmed the lower atmosphere above it, making the lower atmosphere less dense and thereby facilitating rainfall-conducive rising of air. *Id.* at 618.

188. *See id.* at 616. Note that the paper itself did not directly attribute the increasing sea surface temperatures to anthropogenic forcing.

189. Pardeep Pall et al., *Diagnosing Conditional Anthropogenic Contributions to Heavy Colorado Rainfall in September 2013,* 17 WEATHER AND CLIMATE EXTREMES 1, 1 (2017).

190. *Id.* at 5.

191. *See* Martin Hoerling et al., *Northeast Colorado Extreme Rains Interpreted in a Climate Change Context*, in BAMS 2013, *supra* note 178, at S17.

iv. Tropical and Extratropical Cyclones

Climate change can fuel tropical cyclones in several ways. Although key uncertainties remain with respect to how anthropogenic forcing has influenced some tropical cyclone determinants (e.g., wind shear and atmospheric aerosols), other drivers are quite clear. First, sea surface temperatures have warmed in most places, which—all things being equal—allows the most intense storms to strengthen, leading to non-linear increase in storm impacts. Second, a warmer atmosphere can hold more moisture and thus can lead to heavier rainfall and flooding. Finally, higher sea levels exacerbate coastal flooding and high-water levels during storms.

Attribution studies on tropical and extratropical cyclones have generated mixed results. Many early studies performed using the risk-based approach found no clear evidence that anthropogenic forcings altered the probability or severity of the cyclones examined therein.[192] But more recently, there have been numerous studies in which researchers have identified a fairly large anthropogenic "fingerprint" on select storm characteristics. One such study examined 2015 tropical cyclone activity in the western North Pacific Ocean—looking specifically at the level of accumulated cyclone energy (ACE)—and found that anthropogenic forcing largely increased the odds of the ACE values that were observed (FAR = 0.81).[193]

There have also been a number of studies on individual tropical cyclones. Unsurprisingly, for Hurricane Harvey there have been several studies focused on the storm's prodigious rainfall totals, which reached approximately sixty inches. Risser and Wehner, using a statistical approach known as extreme value analysis, found anthropogenic forcing led to 37% more precipitation over land;[194] van Oldenborgh et al. 2017 found a 15% increase using a model

192. *See, e.g.*, Frauke Feser et al., *Hurricane Gonzalo and Its Extratropical Transition to a Strong European Storm*, *in* BAMS 2014, *supra* note 76, at S54; Lei Yang et al., *Anomalous Tropical Cyclone Activity in the Western North Pacific in August 2014*, *in* BAMS 2014, *supra* note 76, at S124.

193. Zhang et al., *Influences of Natural Variability and Anthropogenic Forcing on the Extreme 2015 Accumulated Cyclone Energy in the Western North Pacific, in* BAMS 2015, *supra* note 76 at S133.

194. Mark Risser & Michael Wehner, *Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation During Hurricane Harvey*, 44 GEOPHYSICAL RES. LETTERS 12457, 12457 (2017).

and without considering possible changes in atmospheric dynamics.[195] Allowing for dynamical changes in addition to thermodynamics, Wang et al. 2018 found a ~25% increase.[196] A recent Trenberth 2018 paper showed large positive upper ocean heat content anomalies in advance of Harvey. Upper ocean heat content anomalies are straightforward to link to anthropogenic warming, in so far as the authors note that ~92% of anthropogenically induced warming has gone towards heating the ocean. The authors go on to note that Hurricane Harvey was able to tap the anomalous heat in the nearby upper ocean, ultimately converting the energy into extreme rainfall.[197] While this last paper is not focused on attribution per se, it is emblematic of how broader science advances, past and present, help inform attribution studies—much as attribution studies can advance broader physical understanding. The Trenberth (2018) paper also makes a critical point about non-linearity and threshold crossing of impacts; the authors note that even if precipitation increase with climate change in a storm like Harvey is only 5–15%, that incremental increase could conceivably generate the bulk of all costs. Impacts of hurricane winds have also been shown to increase non-linearly with stronger winds. In the case of the three major landfalling 2017 Atlantic hurricanes, costs were hundreds of billions of dollars.[198]

In contrast to tropical cyclone findings, few attribution studies to date have found an anthropogenic signal in extra-tropical cyclones. One example, Feser et al. (2014), relied on sixty-seven years of observed data and found a recent storm experiencing extra-tropical transition was unexceptional in the context of the long-term observational dataset.[199]

195. Geert Jan van Oldenborgh, *Attribution of Extreme Rainfall from Hurricane Harvey, August 2017,* 12 ENVTL. RES. LETTERS 1, 1 (2017).

196. S. Wang et al., *Quantitative Attribution of Climate Effects on Hurricane Harvey's Extreme Rainfall in Texas*, 13 ENVTL. RES. LETTERS 1, 1(2018).

197. Kevin Trenberth et al., *Hurricane Harvey Links to Ocean Heat Content and Climate Change Adaptation*, 6 EARTH'S FUTURE 730, 730 (2018).

198. Willie Drye, *2017 Hurricane Season Was Most Expensive in U.S. History,* NAT'L GEO. (Nov. 30, 2017).

199. Feser et al., *supra* note 192, at S54.

3. Impact Attribution

Impact attribution focuses on the consequences and outcomes of climate change. Many of the phenomena discussed above (e.g., loss of sea ice, increases in sea levels, and changes in precipitation) can certainly be described as "impacts" of a changing climate[200]—but, as noted at the outset of this section, for the purposes of this paper, we use the IPCC AR5 definition of "impacts":

> In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea level rise, are a subset of impacts called physical impacts.[201]

Impact attribution gets closer to what people really care about in the liability and policy context, and, in particular, the question of who will be harmed by climate change and to what extent. But because impact attribution deals with consequences that are farther along the causal chain, it is harder to issue robust findings about the connection between anthropogenic influence on climate and specific on-the-ground impacts.

a. Methods and Parameters

Impact attribution, like climate change attribution, relies on physical understanding, observational data, statistical analysis, and models. However, impact attribution also involves unique challenges that can make the attribution of impacts more difficult than the attribution of climate change and extreme weather events.

The most fundamental challenge is that, as research moves further down the causal chain from human influence on climate change to discrete impacts on human and natural systems,

200. For example, an "impact" of climate change can be defined as "any change in a physical, biological, or human system that is driven by a long-term climate trend." Cynthia Rosenzweig & Peter Neofotis, *Detection and Attribution of Anthropogenic Climate Change Impacts*, 4 WIREs CLIMATE CHANGE 121, 121 (2013).

201. IPCC AR5 SYR, *supra* note 33, at 124.

researchers must account for an increasing number of non-climate and exogenous variables which complicate the attribution analysis (sometimes referred to as "confounding factors"). For example, in a study seeking to link public health impacts from a heat wave to anthropogenic forcing, researchers would need to account for land use decisions, access to cooling, and other adaptations affecting public health, as well as baseline vulnerability of subsets of the population to heat impacts (based on factors such as age, pre-existing health conditions, and outdoor activity) in order to ascertain the extent to which anthropogenic climate change was responsible for those impacts.

The relationship between two variables can also be complex and non-linear. For example, while the relationship between increasing mortality and each additional degree of warming may be well understood at moderately high temperatures, there may be limited knowledge, or observational basis, of just how steeply mortality may rise with temperature once extreme temperatures occur.[202] Furthermore, there is typically not a linear cause-and-effect relationship, but rather there is an interconnected web of variables where a change in any one variable can create cascading effects and feedback loops. As one example, it has been argued that anthropogenically-enhanced droughts in agricultural breadbaskets, such as Russia in 2010,[203] had cascading impacts on grain prices that disproportionately affected food insecure populations around the globe, ultimately contributing both to malnutrition and civil unrest in regions far away from the original extreme climate event.[204]

Researchers must also account for internal system dynamics in impact attribution studies. For example, a study of how a species' population was impacted by anthropogenic forcing might need to consider the amplitude of long-term population variability due to natural cycles of predator-prey interactions that could in principle be independent of climate. For many systems, and places, standardized long term data sets simply are not available. Furthermore, establishing causation, as opposed to simply observing correlation, can present another challenge, especially for

202. Ebi et al., *supra* note 123, at 085004-3.

203. Rahmstorf & Coumou, *supra* note 110.

204. *See* Troy Sternberg, *Chinese Drought, Bread and the Arab Spring*, 34 APPLIED GEOGRAPHY 519 (2012).

impacts systems where robust models do not exist that allow for simulation of counterfactual worlds, i.e. realizations other than the single realization actually experienced in the real world. In the absence of long-term impact datasets and strong impact models, attribution impact researchers have had to make assumptions. For example, across many impact sectors, short-term weather fluctuations that happened to align with the time period when impacts data were available have been used to estimate sensitivity to climate change,[205] or impacts of earlier events for which data was not available.[206,207] This may be problematic, either because long-term responses inherently differ from short-term responses, or because of changes in the various state variables over time (e.g., long term changes in confounding factors like technological innovation or population change).[208]

Treatment of antecedent climate conditions not being included in the formal attribution analysis requires care as well. For example, a study of flooding damages along a river due to a specific heavy rain event might have to consider how prior meteorological/climate conditions impacted soil moisture, water levels, and even vegetation, as these prior conditions would affect flood extent and damage.

Finally, some of the challenges discussed in the extreme events section apply here as well. For example, the spatial and temporal scale of an impact—and the driving extreme event—may be too fine to capture with existing models. In these instances, large natural variability relative to any anthropogenic signal, absence of

205. *See Oliver* Deschênes & Michael Greenstone, *The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather*, 102 AM. ECON. REV. 3761 (2012); Oliver Deschênes & Michael Greenstone, *Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US*, 3 AM. ECON. J.: APPLIED ECON. 152 (2011).

206. Maximilian Auffhammer et al., *Integrated Model Shows that Atmospheric Brown Clouds and Greenhouse Gases Have Reduced Rice Harvests in India*, 103 PROC. NAT'L ACAD. SCI. 19668, 19670 (2006).

207. To be sure, there are some examples of studies where long-term impact data enabled assessment of long-term changes in impacts. *See* Kristie L. Ebi et al., *Detecting and Attributing Health Burdens to Climate Change*, 125. ENVTL. HEALTH PERSP. 085004-1, 085004-2 (2017) (noting a 2014 study by Bennett et al. on temperature-related mortality in Australia from 1968 to 2007. Charmian Bennett et al. *Shifts in the Seasonal Distribution of Deaths in Australia, 1968–2007*, 58 INT'L J. BIOMETEOROLOGY 835 (2014)).

208. Ebi 2017 provide a strong example: "on a time scale of decades, local food production may shift successfully to new heat-tolerant technologies or be abandoned altogether." Ebi et al, *supra* note 207, at 085004-2 (internal citations omitted).

representative local data, and the aforementioned modeling challenges may hinder impact attribution.

There are a variety of approaches taken in impact attribution studies. Roughly speaking, most impact attribution studies can be characterized as either "single-step" or "multi-step" studies (also known as "direct" and "joint" attribution, respectively). The single-step studies focus on the relationship between impacts and observed changes in mean climate variables or extremes, without going so far as to draw a complete causal connection from the impact to anthropogenic influence on climate. This is similar to the approach taken in the IPCC reports: impacts are discussed in the WGII report but are generally not explicitly linked to human forcings. One key idea underpinning this approach is that human influence is a primary driver of climate change, so we can infer that many of the impacts where attribution is well advanced are ultimately caused by anthropogenic climate change—especially those linked to climate variable, like mean temperature at a continental scale. This approach has the advantage of simplicity, but can only generate robust, quantitative findings where the impact attribution study can be linked to one or more external studies of an appropriate scale and scope, which establish the role of human influence in the change in climate variable giving rise to the impact. In the absence of such studies, scientists may be able to infer that an impact was "caused" by climate change, but they will not be able to isolate the proportional contribution of human influence on that impact. Due to this limitation, many single-step attribution studies tend to communicate results in a conservative fashion, focusing on whether there is *any* human influence on a particular impact rather than quantifying the magnitude of the influence.[209]

The multi-step or "joint" impact attribution studies, which are less common, involve at least two attribution steps: first, linking a change in a mean climate variable or extreme to anthropogenic influence and second, linking impacts to that change.[210] For example, a study could link mortality to temperature increases, and then link temperature increases to greenhouse gas emissions. This

209. IPCC AR5 WGI, *supra* note 25, at 878.

210. For a more detailed explanation of these two approaches, *see* Dáithi Stone et al., *The Challenge to Detect and Attribute Effects of Climate Change on Human and Natural Systems,* 121 CLIMATIC CHANGE 381, 390–91 (2013).

second approach is sometimes referred to as "end-to-end" attribution.[211] The multi-step approach is preferable in principle, but in practice the complexity of multi-step attribution analysis, with its potential for cascading uncertainty, can lead to weak and/or heavily-caveated attribution statements.

A distinction can also be drawn between impact attribution studies that contain quantitative analysis of impacts, and impact attribution studies which only contain a qualitative description of impacts. In quantitative studies, the analysis often mirrors that of extreme event studies—the emphasis being on determining the extent to which climate change increased the risk of certain impacts. Quantitative impact assessments do not always rely on models—sometimes they rely on more simple methods, like extrapolation of observations or historical statistical relationships to estimate impacts such as changes in crop yield. In the qualitative studies, scientists will look at a change like increases in surface temperature, attribute those changes to anthropogenic influence, and then simply describe how the change in the climate variable affected other variables.[212] The advantage of the qualitative approach is that it can provide useful insights into the nature of possible climate change impacts that have not received a great deal of scientific or public attention to date.[213] But the qualitative approach would not be as effective at supporting certain applications, such as liability claims, precisely because it does not generate quantitative data.

b. Status of Research

The WGII report for AR5 found strong evidence that "changes in climate have caused impacts on natural and human systems on all continents and across all oceans" in recent decades.[214] However, it also found that evidence of climate-change impacts was "strongest

211. *See, e.g.*, Cynthia Rosenzweig et al., *Attributing Physical and Biological Impacts to Anthropogenic Climate Change* 453 NATURE 353, 354 (2008).

212. *See, e.g.*, Michael Jacox et al., *Forcing of Multiyear Extreme Ocean Temperatures that Impacted California Current Living Marine Resources in 2016*, *in* BAMS 2016, *supra* note 76, at S27.

213. BAMS annual extreme event attribution reports, for example, are increasingly weighing in on impacts *after* assessing whether the extreme event can be linked to anthropogenic forcing. The majority of the papers address the link between the impact and the extreme event in a qualitative way, with a few exceptions.

214. IPCC AR5 WGII, Summary for Policymakers, *supra* note 20, at 4.

and most comprehensive" for natural systems, whereas evidence linking impacts on human systems to climate change was more limited.[215] Most of the attribution findings in the WGII report are the product of "single-step attribution" although the report does cite to some studies that have conducted multi-step attribution. In recent years, the BAMS reports have also been expanded to encompass impacts attribution in addition to extreme event attribution, and most of the studies in those reports employ single-step attribution.[216] Two key areas of focus in impact attribution studies include the Arctic and the oceans, where changes are occurring more rapidly and impacts are therefore more apparent. Impacts from extreme events, particularly heat waves, are also a major focus of impact attribution studies.

i. Ecosystems, Species, and Ecological Indicators

Much of the existing impact attribution research focuses on ecological impacts, seeking to understand how climate change is affecting individual species, ecosystems, and ecological functioning. The focus of such studies is on natural systems, but there are clear implications for human systems, insofar as we rely on natural systems, such as fisheries, for food as well as other ecosystem services, such as water and air filtration. There is robust evidence of impacts in this category. In particular, IPCC AR5 found with *high confidence* that "[m]any terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, and abundances, and species interactions in response to ongoing climate change."[217] IPCC AR5 also expressed *high confidence* in findings that several recent species extinctions can be attributed to climate change,[218] and *very high confidence* that climate-related extremes such as heat waves, droughts, floods, and cyclones were altering ecosystems.[219] IPCC AR5 expressed *high* and *medium confidence* about a number of other region-specific impacts,

215. *Id.*

216. Herring et al., *supra* note 151, at S3. As noted earlier, in the BAMS reports, the single-step tends to be the link between anthropogenic warming and climate or extreme events, with the link to impacts treated less rigorously.

217. IPCC AR5 WGII, Summary for Policymakers, *supra* note 18, at 4. Note the absence, though, of direct attribution of the climate change to anthropogenic forcing, rather than other possible factors, like natural variability.

218. *Id.*

219. *Id.* at 6.

such as changes in the timing of critical biological events, increased tree mortality, pest outbreaks, and other ecosystem disturbances.[220]

There are many examples of both single-step and multi-step attribution of ecological impacts. Most of the multi-step studies focus on the impact of increasing temperatures on biological systems.[221] In one of the earliest and most comprehensive meta-analyses, Rosenzweig et al. 2008 conducted a broad assessment of observed changes in natural systems.[222] The researchers demonstrated that: (i) regional climate changes were caused by human forcing, and (ii) observed changes in natural systems were consistent with the estimated responses of physical and biological systems to regional climate change and not consistent with alternative explanations that exclude regional climate change. Specifically, they found that approximately 95% of 829 documented physical changes (e.g., glacier reduction and earlier spring peak of river discharge) and that 90% of 28,800 documented changes in biological systems (e.g., earlier blooming) were in directions consistent with warming.[223] The researchers endeavored to explicitly account for confounding variables such as land use change, management practices, pollution and human demography shifts.

Many other impact studies have been conducted since 2008 to improve understanding of exactly how climate change is affecting biological systems. The 2016 BAMS report contained several examples of such studies, including three studies finding that increases in sea surface and ocean temperatures were harming ocean ecosystems through impacts such as coral reef bleaching and reduced fish stocks,[224] and a study on terrestrial impacts which found that anthropogenic influence on climate change was actually driving higher ecosystem productivity on the Iberian Peninsula

220. IPCC AR5 WGII, Technical Summary, *supra* note 18, at 44–46.

221. *See, e.g.*, Terry Root et al., *Human-Modified Temperatures Induce Species Changes: Joint Attribution*, 102 PROC. NAT'L ACAD. SCI. 7465 (2005); Ebi et al., *supra* note 207.

222. Cynthia Rosenzweig et al., *Attributing Physical and Biological Impacts to Anthropogenic Climate Change*, 453 NATURE 353, 354 (2008).

223. *Id.* While those key findings were presented in quantitative terms, each documented change was handled in a qualitative way (looking at direction of change and not amount changed).

224. Sophie C. Lewis & Jennie Mallela, *A Multifactor Risk Analysis of the Record 2016 Great Barrier Reef Bleaching*, *in* BAMS 2016, *supra* note 76, at S144; Jacox et al., *supra* note 212; Russel E. Brainard et al., *Ecological Impacts of the 2015/16 El Niño in the Central Equatorial Pacific*, *in* BAMS 2016, *supra* note 76, at S21.

through warmer winters coupled with wet springs and increases in CO_2 availability.[225] These studies exemplified the diversity of approaches in impact attribution: one of the marine studies focused on the role of anthropogenic forcing in causing ocean temperatures that had resulted in certain ecological impacts without taking a detailed look at the impacts themselves;[226] another focused on the extent to which coral reef and seabird communities were disrupted by record-setting sea surface temperatures and made an "indirect two-step link to human-induced climate change" by referencing findings from a companion paper attributing the record-setting temperatures to anthropogenic forcing;[227] and the third was a multi-step attribution study in which scientists attributed abnormally warm SST to anthropogenic forcing and then qualitatively examined the respective role of the abnormally warm SST on coral bleaching.[228] The multi-step attribution study of the Iberian Peninsula was noteworthy for the complexity of the model design, which included counterfactual simulations for both the climate model and the ecosystem model. The experimental design supported attribution of ecosystem impacts not only to observed changes in climate associated with anthropogenic forcing, but also to direct impacts of higher CO_2 concentrations on vegetation.[229]

As evident from these and other studies, impacts on marine ecosystems are a key topic in impact attribution. One reason for this is ocean temperatures are rising quickly in many regions relative to natural variability (indicating a high signal to noise ratio).[230] Not coincidentally, the impacts on marine resources are more evident, in some cases, than terrestrial impacts, as more and more species and ecosystems approach climate thresholds that may not have occurred during their evolutionary history. The effect of climate change on fishery productivity is also a major concern throughout the world and a key focus of many studies.[231]

225. Sippel et al., *supra* note 111, at S80.

226. Jacox et al., *supra* note 212.

227. Stott et al., *Future Changes in Event Attribution Methodologies, in* BAMS 2016, *supra* note 76, at S156 (referencing Brainard et al., *supra* note 224).

228. Lewis & Mallela, *supra* note 224.

229. Sippel et al., *supra* note 111.

230. Thomas Frölicher, et al., *Marine Heatwaves Under Global Warming*, 560 NATURE 360, 360 (2018).

231. *See, e.g.,* NAT'L OCEANIC AND ATMOSPHERIC ADMIN., WHAT CAUSED THE SACRAMENTO RIVER FALL CHINOOK STOCK COLLAPSE? (2009); Jonathan A. Hare et al., *Cusk (Brosme brosme) and Climate Change: Assessing the Threat to a Candidate Marine Fish Species Under the US*

ii. Inland Flooding and Hydrologic Impacts

A fair amount of research has also been conducted on the impacts of climate change on inland or riverine floods, hydrologic droughts, and changes in streamflow. Above, we discuss meteorological droughts as a type of extreme climate event—hydrologic droughts are more properly classified as "impacts" of climate change because there are so many confounding factors that affect their characteristics. The same can be said for floods. While these are often discussed as "extreme events" in common parlance, they are more properly classified as impacts of climate change due to the number of non-climate related confounding factors that affect flood characteristics.[232] It is also worth bearing in mind that floods and other hydrologic impacts can be affected by slow-onset changes such as temperature increases as well as extreme events. IPCC AR5 found, with *medium confidence,* that changes in precipitation, snow melt, and ice are altering hydrological systems and affecting water resources (both in terms of quality and quantity).[233] However, IPCC AR5 did not find evidence that, on a global scale, surface water and groundwater drought frequency had changed in the last few decades,[234] but did discuss research linking regional drought conditions to climate change.[235] IPCC AR5 also found with *very high confidence* that climate-related extremes were disrupting water supply.[236]

Flood attribution studies follow the same pattern as other impact attribution studies—single-step attribution, as well as storyline approaches dominate existing studies to date.[237] The climate variables that are most relevant to inland flood impact analysis include precipitation, storms, and temperature (which can cause flooding through, e.g., snowmelt and permafrost thawing). Some multi-step analyses have also been performed for hydrologic

Endangered Species Act, 69 ICES J. MARINE SCI. 1753 (2012); Kyle Meng et al., *New England Cod Collapse and the Climate*, PLOS ONE, July 27, 2016.

232. These include, for example, geography, topography, hydrology, water infrastructure, land use decisions, and building design. Note though that precipitation associated with a flood would be treated as an "extreme event" under our nomenclature.

233. IPCC AR5 WGII, *supra* note 18, at 44.

234. *Id.*

235. *See, e.g.*, *id.* (expressing *medium confidence* that climate change had increased soil moisture drought in the Sahel since 1970).

236. *Id.* at 6.

237. *See, e.g.*, Trenberth et al., *supra* note 125.

droughts and other hydrologic impacts.[238] For example, a 2008 study of human-induced changes in the hydrology of the western United States found that up to 60% of the climate-related trends in river flow, winter air temperature, and snow pack between 1950 and 1999 were human-induced.[239]

iii. Coastal Impacts

Climate change is affecting coastlines through sea level rise, changes in the severity and frequency of storms and extreme rainfall events, temperature changes (particularly marine temperatures), and ocean acidification. IPCC AR5 found that many coastal areas are already experiencing adverse impacts such as submergence, coastal flooding, coastal erosion, and saltwater intrusion, all of which are exacerbated by sea level rise, but found also that the impacts of anthropogenic climate change on coastlines are difficult to tease apart from human-related drivers such as land use change and in situ adaptations such as sea walls.[240] Studies attributing coastal impacts to anthropogenic influence on climate may focus exclusively on physical impacts or may seek to link physical impacts to economic or public health outcomes.

Findings from recent coastal impact studies suggest that some coastal areas are already undergoing dramatic transformations driven primarily by sea level rise. For example, one single-step study of flooding in Southeast Florida focused on the role of sea level rise in monthly high tides and found that the probability of a 0.57-meter tidal flood within the Miami region had increased by more than 500% since 1994 due to a 10.9-centimeter increase in sea levels.[241] The findings from this study are compelling—indeed both the link between 1) anthropogenic warming and sea level rise and 2) sea level rise and the frequency of coastal flooding are two

238. *See, e.g.*, Sebastian Sippel & Friederike E. L. Otto, *Beyond Climatological Extremes—Assessing how the Odds of Hydrometeorological Extreme Events in South-East Europe Change in a Warming Climate*, 125 CLIMATIC CHANGE 381 (2014); Pardeep Pall et al., *Anthropogenic Greenhouse Gas Contribution to Flood Risk in England and Wales in Autumn 2000*, 470 NATURE 382 (2011); Geert Jan van Oldenborgh et al., *The Absence of a Role of Climate Change in the 2011 Thailand Floods, in* EXPLAINING EXTREME EVENTS OF 2011 FROM A CLIMATE PERSPECTIVE 1047 [hereinafter BAMS 2011] (2012).

239. Tim Barnett et al., *Human-Induced Changes in the Hydrology of the Western United States*, 319 SCIENCE 1080, 1080 (2008).

240. IPCC AR5 WGII, *supra* note 18, at 364.

241. William V. Sweet et al., *In Tide's Way: Southeast Florida's September 2015 Sunny-day Flood, in* BAMS 2015, *supra* note 76, at S25.

of the most robust aspects of climate change. Nevertheless, this and similar studies are limited insofar as they do not quantify the anthropogenic influence on the observed changes in sea level rise and corresponding impact on floods, nor do they speak to specific impacts on human systems (e.g., economic damages or public health outcomes).

iv. Wildfires

Climate change primarily exacerbates wildfire risk through hotter and drier conditions. Perhaps counterintuitively, in water-limited regions, an unusually wet growing season, during which time more vegetation grows which can later become fuel, can set the stage for a large fire season once the vegetation dries out. Winds, atmospheric humidity, solar radiation, and lightning strikes also influence fire risk. While wildfires are sometimes characterized as "extreme events" related to climate change, they are far from purely meteorological events; rather, they are a product of both climatological and terrestrial conditions. For example, the expansion of human development and electrical systems into previously-remote forest zones leads to an increase in ignition, and forest management and fire suppression decisions affect fire frequency and intensity.[242] As such, the link between climate change and wildfires is less direct than the link between climate change and events such as heat waves. IPCC AR5 expressed *medium* and *low confidence* in various studies linking increases in the severity or frequency of wildfires to climate change,[243] with the higher confidence for wildfires in data-rich North America. Research performed since then has generated more robust evidence of a link between *anthropogenic* climate change and wildfires in North America and Australia.[244]

242. A. Park Williams et al., *Observed Impacts of Anthropogenic Climate Change on Wildfire in California*, 7 EARTH'S FUTURE 892, 892 (2019) (recognizing that the effects of climate change on wildfire can vary greatly across space and time due to confounding factors such as fire suppression and ignitions from humans).

243. *See, e.g.*, IPCC AR5 WGII, *supra* note 18, at 44 (*low confidence* that climate change had increased wildfires on Mt. Kilamanjaro); *id.* at 45 (*medium confidence* that climate change increased wildfire frequency in subarctic conifer forests and tundra, and *medium confidence* that climate change increased wildfire activity, fire frequency, and duration in forests of Western U.S. and boreal forests in Canada).

244. NCA4, *supra* note 7, at 242-245.

One of the earliest studies on this topic, published in 2004, found that human-induced climate change had a detectable influence on Canadian forest fires in recent decades[245] A 2016 end-to-end study on wildfires in the western United States found that, while there were numerous factors that aided the recent rise in fire activity, observed warming and drying had significantly increased fuel aridity during the fire season, fostering a more favorable environment for wildfires.[246] They found that anthropogenic climate change caused over half of the documented increases in fuel aridity since the 1970s and doubled the cumulative forest fire area since 1984.[247] The same researchers published a subsequent study focused on California which found that human-induced warming had already significantly enhanced wildfire activity in the state, particularly in the forests of the Sierra Nevada and North Coast.[248] Another end-to-end study focusing on the role of extreme vapor pressure deficits (VPD) in wildfire risk found that anthropogenic influences quintupled the risk of extreme VPD for western North America and had doubled the risk of extreme VPD in extratropical Australia.[249]

Again, the findings from these studies are compelling, but like many impact studies, they rely on proxies for wildfire risk such as fuel aridity in order to attribute impacts. Further studies can help continue to provide answers to help quantify the extent to which anthropogenic climate change has caused an increase in wildfires as compared with other confounding factors such as fire suppression and development in wildfire-prone areas.

245. N.P. Gillett et al., *Detecting the Effect of Climate Change on Canadian Forest Fires*, 31 GEOPHYSICAL RES. LETTERS 1, 1 (2004).

246. John Abatxoglou & A. Park Williams, *Impact of Anthropogenic Climate Change on Wildfire Across Western US Forests,* 113 PROC. NAT'L ACAD. SCI. 11770, 11770 (2016).

247. *Id.*

248. A. Park Williams et al., *supra* note 242, at 892 (more specifically, the authors found that anthropogenic climate change had contributed to an eightfold increase in summertime forest-fire area, which in turn had contributed to a fivefold increase in California's annual wildfire extent).

249. Simon F.B. Tett et al., *Anthropogenic Forcings and Associated Changes in Fire Risk in Western North America and Australia During 2015/16, in* BAMS 2016, *supra* note 76, at S60–64.

v. Air pollution

There have been relatively few attribution studies of air pollution. Vautard 2018 looked indirectly at air pollution in Europe.[250] Rather than modeling actual air pollution, they modeled changes in the occurrence of "flow analogues" (i.e. wind and air pressure patterns associated with observed historical pollution events), finding that anthropogenic forcing had produced a 10% increase in the frequency of such events. As climate models become more able to model air pollution directly, and as awareness grows of how harmful fire and directly anthropogenic sources of air pollution (e.g., factories and vehicle emissions) are, we may see more attribution work on air pollution. Such studies will have to address the correlation between climate and air pollution, which differs by region, season, and type of pollutant.

vi. Public Health

Public health impacts are another important topic in attribution research. Here, again, many studies focus on how extreme heat affects health because the link between climate change and extreme heat is relatively direct. There has been much discussion of how other climate-related events and impacts, such as floods and wildfires, can affect public health, but there is little research linking anthropogenic forcings to health impacts from those types of events in a robust, quantitative fashion. As noted in IPCC AR5, evidence of impacts on public health is not as robust as evidence of other impacts, and "[a]t present the worldwide burden of human ill-health from climate change is relatively small compared with effects of other stressors and is not well quantified."[251] However, IPCC AR5 did find more robust evidence of specific types of health impacts, expressing *medium confidence* in findings of increased heat-related mortality and decreased cold-related mortality in some regions as a result of warming, *medium confidence* that local changes in temperature and rainfall have altered the distribution of some water-borne illnesses and disease vectors,[252] and *very high confidence*

250. *See* Robert Vautard et al., *Attribution of wintertime anticyclonic stagnation contributing to air pollution in Western Europe, in* BAMS 2016, *supra* note 76, at S70–75.
251. IPCC AR5 WGII, Summary for Policymakers, *supra* note 18, at 6.
252. *Id.*

that climate-related extremes were affecting morbidity, mortality, mental health, and human well-being.[253]

Attribution of public health impacts, like other impacts, is challenging due to data requirements and the complexity of isolating causal factors that contribute to health outcomes. As noted by Ebi et al. 2017, robust detection and attribution of health impacts requires reliable long-term datasets, in-depth knowledge of the many drivers and confounding factors that affect public health outcomes, and refinement of analytic techniques to better capture the effect of anthropogenic forcing on health outcomes.[254] Two key challenges are the fact that high-quality, long-term public health data is not available for many parts of the world, and there are many confounding factors that influence public health outcomes in any given region.

Despite the limitations, Ebi et al. 2017 found that "advances are possible in the absence of complete data and statistical certainty: there is a place for well-informed judgments, based on understanding of underlying processes and matching of patterns of health, climate, and other determinants of human well-being."[255] To illustrate this point, the researchers discuss several contexts in which it is possible to show that a "proportion of the current burden of climate-sensitive health outcomes can be attributed to climate change": (i) heat waves, (ii) the emergence of tick vectors of Lyme disease in Canada, and (iii) the emergence of *Vibrio* in northern Europe. For heat waves, the researchers described several approaches for estimating the number of heat wave deaths attributable to anthropogenic climate change. These included two variants on multi-step attribution that would combine either the risk-based or storyline approach to extreme event attribution with an assessment of how changes in exposure to heat waves affect mortality, as well as a single-step attribution approach which would combine observations of the changes in the incidence and severity of heat waves with the exposure analysis. For *Vibrio*, the researchers found that it was possible to attribute increases in the incidence of *Vibrio* to incremental increases in sea surface temperatures, which could then be attributed to climate change. For tick vectors and Lyme disease, the researchers found that there was indirect

253. *Id.*
254. Ebi et al., *supra* note 207, at 085004-1.
255. *Id.*

evidence that higher temperatures were one of the forces leading to the expansion of these vectors, but that more detailed analyses of longer-term surveillance data was needed to actually quantify the relationship between climate change and tick vectors. One key takeaway from the authors of that study was that there are many different approaches to health impact attribution but no standard practice at this time.

Single-step attribution is still routinely used in health impact assessments. One such study looked at heat-related mortality in Sweden and found that mortality from heat extremes in 1980–2009 was double what would have occurred without climate change.[256] As noted, the key limitation to these studies is that they do not answer the question of how *anthropogenic* climate change is affecting public health.

The first fully quantitative end-to-end attribution analysis of heat-related morality from climate change was published in 2016.[257] This study combined a climate model with a health impact assessment model to attribute deaths from the 2003 European heat wave and found that anthropogenic climate change increased the risk of heat-related mortality by approximately 70% in Central Paris and 20% in London, and that approximately 506 (± 51) deaths were attributable to climate change in Paris, and 64 (± 3) deaths were attributable in London.[258]

Where data on public health outcomes is lacking, researchers may use changes in climate variables as proxies for health impacts. For example, a study on public health impacts from extreme temperatures in California's Central Valley used a temperature threshold of 40°C as a proxy for heat stress, and found that anthropogenic forcing had more than doubled the probability of a prolonged period (13+ days) during which temperatures exceeded that threshold).[259] Another study took a similar approach to examining health impacts from the 2015 Egyptian heat wave, using

256. Daniel Oudin Åström et al., *Attributing Mortality from Extreme Temperatures to Climate Change in Stockholm, Sweden*, 3 NATURE CLIMATE CHANGE 1050, 1051. (2013). The researchers accounted for confounding variables such as urbanization and the urban heat island effect, but did not attempt to quantify human influence on observed increases in extreme heat events.

257. Daniel Mitchell et al., *Attributing Human Mortality During Extreme Heat Waves to Anthropogenic Climate Change* 11 ENVTL. RES. LETTERS 1, 1 (2016).

258. *Id.*

259. Roberto Mera et al., *Climate Justice and the Application of Probabilistic Event Attribution to Summer Heat Extremes in the California Central Valley*, 133 CLIMATIC CHANGE 427, 435 (2015).

wet bulb globe temperature as a proxy for human discomfort caused by high heat and humidity, and found that the wet bulb temperatures observed during the heat wave were 69% more likely due to anthropogenic climate change.[260] This indirect approach to impact attribution is essentially the same as extreme event attribution but with a greater focus on implications for health outcomes. By construction, such studies assume a fixed relationship between the climate or climate extreme metric being calculated (e.g., a wet bulb temperature threshold) and the societal impact (additional mortality). This fixed approach may limit the applicability of the findings across places, subpopulations, and adaptation/policy contexts.

vii. Agriculture

Agricultural impacts, like public health impacts, are challenging to attribute to anthropogenic climate change due to gaps in data and the number of confounding factors that influence agricultural productivity.[261] One important finding from the research thus far is that climate change is having both positive and negative effects on agriculture depending on the region examined. Based on multiple studies covering a wide range of regions and crops, IPCC AR5 found with *high confidence* that "negative impacts of climate change on crop yields have been more common than positive impacts."[262] IPCC AR5 also found with *very high confidence* that climate-related extremes were disrupting the food supply.[263]

Attribution studies on agricultural impacts focus on linking observed changes in crop productivity to observed changes in temperature, rainfall, atmospheric greenhouse gas concentrations,

260. Daniel Mitchell, *Human Influences on Heat-Related Health Indicators During the 2015 Egyptian Heat Wave, in* BAMS 2015, *supra* note 76, at S72.

261. Agriculture and ecosystems are directly impacted by CO_2 concentrations. There is also growing research on how other pollutants associated with anthropogenic emissions (or byproducts of those emissions), like low-level ozone, may impact crops, ecosystems, and human health. For example, one recent study found a 10% decrease in soy production associated with and elevated ozone concentrations linked to anthropogenic ozone precursors. The fact that these chemical reactions are highly sensitive to temperature and other climate factors points at the challenges of quantifying results. Wolfgang Cramer et al., *Detection and Attribution of Observed Impacts*, in CLIMATE CHANGE 2014: IMPACTS, ADAPTATION 979-1037 (Christopher B. Fields et al eds., 2014).
and Vulnerability

262. IPCC AR5 WGII, Summary for Policymakers, *supra* note 18, at 4.

263. *Id.* at 6.

and extreme events. Some of the earliest studies on this topic demonstrated that declining crop yields co-occurred with anthropogenic summer warming at regional scales.[264] A more recent end-to-end study on how anthropogenic climate change affected drought and poor harvests in South Africa during 2016 found that anthropogenic forcings had likely contributed to a decrease in rainfall corresponding with a decrease in production, but did not go so far as to quantify precise impacts on crop productivity or economic damages.[265]

viii. Economics and Development

All of the changes in weather, extreme events, and impacts caused by climate change have implications for the economic health, stability, and social development of communities and nations. The primary drivers of these economic and development impacts include: 1) physical impacts on infrastructure and human settlements (e.g., from sea level rise and storms); 2) impacts on public health and human productivity; and 3) impacts on food production.[266] Quantifying these impacts is particularly challenging, as this requires quantification of all the different types of impacts discussed above, and more. But some initial efforts have been made to do so. IPCC AR5 highlighted several examples of studies drawing a qualitative link between observed climate changes and/or impacts and the corresponding effect on regional or national economic outcomes. For example, IPCC expressed *high confidence* in the fact that "extreme weather events currently have significant impacts in multiple economic sectors" in Europe.[267]

264. *See* David B. Lobell & Christopher B. Field, *Global Scale Climate-Crop Yield Relationships and the Impacts of Recent Warming*, 2 ENVTL. RES. LETTERS 1, 1 (2007); Lianzhi You et al., *Impact of Growing Season Temperature on Wheat Productivity in China*, 149 AGRIC. FOREST METEOROLOGY 1009, 1009 (2007); David B. Lobell et al., *Climate Trends and Global Crop Production Since 1980*, 333 SCIENCE 616, 616 (2011).

265. Chris Funk et al., *supra* note 177, at S91.

266. For example, the 2017 and 2018 wildfires in California caused billions of dollars of damage. Facing the prospect of liability for many of those fires, Pacific Gas and Electric (PG&E), one of the largest utilities in the United States, has filed for bankruptcy. While there has not yet been a formal attribution study establishing the causal link between anthropogenic climate change and those fires, initial analyses suggest that unusually warm temperatures did play a role. Kurtis Alexander, *Scientists See Fingerprints of Climate Change All Over California's Wildfires*, S.F. CHRON. (Aug. 3, 2018), https://www.sfchronicle.com/science/article/Scientists-see-fingerprints-of-climate-change-all-13128585.php. [https://perma.cc/TUK4-TMW6].

267. IPCC AR5 WGII, *supra* note 18, at 42.

IPCC AR5 also cited some specific examples of economic and social impacts from climate-related events, such as the 2008 Zambezi River flooding in Mozambique which displaced 90,000 people.[268] IPCC also highlighted research linking higher temperatures to declines in economic growth and per capita income in low-income countries,[269] and linking declining rainfall to the slower growth of Sub-Saharan economies,[270] but this research did not address the extent to which anthropogenic influence was responsible for observed impacts.

4. Source Attribution

We use the term "source attribution" in this paper to describe efforts to identify and attribute climate change to specific sources. A "source" could be a particular actor (e.g., a country or a company), a sector, or an activity. As one step in the longer chain to source attribution, we include efforts to unpack the relative contributions of different sources to greenhouse gas emissions and concentrations. As noted above, source attribution has been, and remains, a distinct discipline from what is commonly labeled "detection and attribution" in the climate science community.[271] However, the distinction is beginning to blur, as recent studies have endeavored to apply climate change and extreme event attribution to individual sources. This research is thus a critically important data point for societal questions about how we should allocate *responsibility* for climate change and its impacts among different actors—and these questions are at the heart of many policy, planning, and legal debates.

a. Methods and Parameters

As discussed above, the key sources of data used in source attribution come from direct measurements of emissions, which can be performed *in situ* or remotely from satellites, as well as documentary evidence of emissions contained in corporate reports,[272] government inventories, and other sources. Where

268. *Id.*
269. *Id.* at 997.
270. *Id.*
271. *See supra* Section II(A)(1).
272. These are most often emissions reports, although some historical emissions have been estimated based on production reports.

direct emissions data is lacking, scientists can use indirect methods, such as models, to estimate emissions from sources and activities. Indirect methods are particularly important for estimating emissions from land use changes and non-point sources such as agricultural operations.

As with other areas of attribution, it is challenging to establish a complete causal chain linking a source's contribution to climate change to specific changes in the global climate system and corresponding impacts on natural and human systems. Establishing such a causal chain involves going beyond merely quantifying the emissions contribution of the source and ascertaining the proportional contribution of those emissions to: (i) concentrations of greenhouse gases and other forcings, and (ii) ultimately how those changes in concentrations impact for example sea level rise, extreme weather events, and the resultant impacts on ecosystems and/or communities. There are some recent studies linking specific sources to certain changes in the global climate system but most of the existing research on "source attribution" focuses on quantifying emissions from sources and determining the proportional contribution to increases in atmospheric greenhouse gases.[273]

One complicating factor is that climate change is not a product of a single pollutant or polluting activity, and different GHGs and other forcing agents have different effects on climate in terms of magnitude, duration, location, and type of effect.[274] For example, aerosols typically reflect sunlight, and to generalize due to this and other aerosol properties, aerosols tend to offset some of the heat-trapping effects of greenhouse gases. Data gaps are a major issue here: there are no known industry-aerosol databases, although there have been efforts to estimate national aerosol contributions.[275] This is important because large uncertainty about the emissions or climate effects of a single important forcing agent (like aerosols) affects our estimates for other forcing agents.

There is also a good deal of uncertainty about the extent and timing of historical land use changes and their impact on atmospheric concentrations of greenhouse gases. Some of these

273. *See infra* Section II(B)(4)(b)(ii).

274. *See supra* Section II(B)(1).

275. *E.g.*, Ragnhild B. Skeie et al., *Perspective Has a Strong Effect on the Calculation of Historical Contributions to Global Warming*, 12 ENVTL. RES. LETTERS 1 (2017).

land use changes, like deforestation, also impact climate in other ways. For example, land use decisions which change the amount of sunlight absorbed at the surface can have an important or negligible effect on climate, depending on factors such as the latitude at which the deforestation occurs, and the reflective properties of the surface underneath the previously-forested area. Another complicating factor is that climate change itself directly impacts the magnitude of sources and sinks for greenhouse gases. For example, a warmer ocean is less able to uptake carbon dioxide, and changes in vegetation with climate change could switch some natural systems from net sources to net sinks, and vice versa.

Nonetheless, scientists can and have endeavored to calculate the relative contributions of emissions and land use change, and, within the category of emissions, of different pollutants. In climate change attribution studies, scientists can bolster emissions data with actual measurements of atmospheric greenhouse gases (such as those taken at Mauna Loa) to determine the overall effect of human activity on climate, with the aforementioned caveats. In source attribution, an estimate of total anthropogenic emissions is the denominator against which a specific source's emissions contribution can be compared. Consider the following equation as an illustration of this concept:

$$Cs = Gs/Gg$$

Here, *Cs* equals the source's proportional contribution to climate change, *Gs* equals greenhouse gases generated by the source (including any releases or loss in carbon sequestration caused by the source), and *Gg* equals total global greenhouse gases from all anthropogenic sources. The measurements of atmospheric greenhouse gases help scientists quantify *Cs*, but they do not provide much if any insight on the magnitude of the source's emissions.

Another complicating factor is how to account for historical emissions when ascertaining the proportional contribution of a source to climate change. Given that greenhouse gases accumulate over time, stay in the atmosphere, and can even have lasting climate effects that extend beyond the time that the added gas is in the atmosphere, it makes sense to include historical emissions in source attribution studies. But data about historical emissions is much more limited, given the absence of satellite-based observations and other data sources, less rigorous reporting requirements, and disappearance over time of some emitting entities and documents.

The steps from 1) emissions estimates to concentration estimates, and from 2) concentration estimates to climate effects like warming surface temperature and sea level rise, require the use of models. Although full climate models are beginning to be applied to attribution based on individual source estimates, most of the research described below relies on simplified climate models that can conduct rapid simulations based on differing source emissions. These simplified models enable sundry experiments for example based on individual country emissions, but some fidelity is sacrificed for the greater speed and simplicity. These models include assumptions about certain climate parameters (e.g., *equilibrium climate sensitivity*—which can be loosely defined as the final global warming associated with a certain amount of additional forcing, often defined as a doubling above preindustrial CO_2 equivalent; and *transient response*, a measure of more rapid climate system response).

This question of how to account for historical emissions brings us back to an earlier point about the role of social science in source attribution. As explained above, physical sciences alone cannot fully answer the question of who is "responsible" for emissions because responsibility can be apportioned in many different ways. There are presently two primary approaches—assigning responsibility to national governments and assigning responsibility to private actors—but there are also questions about how to apportion responsibility under each approach.[276]

International climate negotiations have historically focused on using national responsibility as the basis for allocating emission reduction burdens.[277] This focus is evident in the United Nations

276. *See supra* Section II(A)(2)(c) (national emissions contributions could be calculated based on emissions generated within national boundaries or emissions embedded within consumed products; private sector emissions from fossil fuel consumption could be apportioned to fossil fuel production companies, power plants, or consumers).

277. A Brazilian proposal taken up by the UNFCCC Subsidiary Body for Scientific and Technical Advice (SBSTA) said national historical emissions impacts on temperature should determine the burden of addressing climate change. A rationale provided was that these countries had benefitted economically and geopolitically from their emissions. For more information about the Brazilian proposal and the underlying rationale for this approach, *see* Emilio L. La Rovere et al., *The Brazilian Proposal on Relative Responsibility for Global Warming, in*

Framework Convention on Climate Change (UNFCCC), which places the responsibility for reporting on and reducing emissions on national governments;[278] the so-called "Brazilian Proposal" which emerged from UNFCCC negotiations in the mid-1990s and holds that greenhouse gas emission reduction targets should be set according to each country's historical contribution to climate change;[279] and the Paris Agreement which relies on nationally determined contributions (NDCs) as the primary basis for mitigating emissions.[280] The UNFCCC reporting framework has also historically focused on territorial emissions rather than consumption-based emissions as the metric for gauging national responsibility.

That said, in recent years there has been a strong push both in international and domestic fora to: (i) account for consumption-based emissions as well as territorial emissions at the national level,

BUILDING ON THE KYOTO PROTOCOL: OPTIONS FOR PROTECTING THE CLIMATE (Kevin A. Baumert et al. eds., 2002); BENITO MULLER ET AL., DIFFERENTIATING (HISTORIC) RESPONSIBILITIES FOR CLIMATE CHANGE (2007); M.G.J. DEN ELZEN ET AL., DUTCH MINISTRY OF ENV'T, RESPONSIBILITY FOR PAST AND FUTURE GLOBAL WARMING: TIME HORIZON AND NON-LINEARITIES IN THE CLIMATE SYSTEM (2002); Nathan Rive et al., *Climate Agreements Based on Responsibility for Global Warming: Periodic Updating, Policy Choices, and Regional Costs,* 16 GLOBAL ENVTL. CHANGE 182 (2006); Kevin A. Baumert & Nancy Kete, *Introduction: An Architecture for Climate Protection,* in BUILDING ON THE KYOTO PROTOCOL: OPTIONS FOR PROTECTING THE CLIMATE (Kevin A. Baumert et al. eds., 2002); Stephen Gardiner, *Ethics and Global Climate Change*, 114 ETHICS 555 (2004). More recently, Underdal and Wei reference "accumulated competitive advantages" via technological innovation and economic growth as the source of Annex 1 higher wealth today. Arild Underdal & Taoyuan Wei, *Distributive Fairness: A Mutual Recognition Approach*, 51 ENVTL. SCI. POL'Y 35, 37 (2015). The Annex 1 countries have argued against apportionment of responsibility based on historical emissions, on the grounds that, they were not aware of the effects of greenhouse gas emissions until ~1990, when the IPCC described these effects in detail. *See* JYOTI PARIKH & KIRIT PARIKH, CLIMATE CHANGE: A PARKING PLACE MODEL FOR A JUST GLOBAL COMPACT (2009). Others have countered that there were many earlier warnings about the perils of greenhouse gas emissions. *See, e.g.*, PRESIDENT'S SCI. ADVISORY COMM., RESTORING THE QUALITY OF OUR ENVIRONMENT (1965); Wallace S. Broeker, *Climatic Change: Are We on the Brink of a Pronounced Global Warming?,* 189 SCIENCE 460–64; WORLD METEOROLOGICAL ORGANIZATION, PROCEEDINGS OF THE WMO/IAMAP SYMPOSIUM ON LONG-TERM CLIMATIC FLUCTUATIONS, WMO Doc. 421 (Aug. 1975); NAT'L ACAD. OF SCI., CARBON DIOXIDE AND CLIMATE: A SCIENTIFIC ASSESSMENT (1979). Based on this record, Mattoo and Subramanian (2012) argued for 1970 as the start year. Aaditya Mattoo & Arvind Subramanian, *Equity in Climate Change: An Analytical Review*, 40 WORLD DEV. 1083 (2012).

278. United Nations Framework Convention on Climate Change, May 9, 1992, S. Treaty Doc No. 102-38, 1771 U.N.T.S. 107 [hereinafter UNFCC].

279. La Rovere et al., *supra* note 277.

280. Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104 [hereinafter Paris Agreement].

and (ii) impose direct responsibility on private actors for emissions and to impose corresponding obligations on those actors.[281] Much of the focus has been on imposing regulatory requirements or liability for climate change on fossil fuel producers and electric generating companies. This brings us to another question about divvying up responsibility for emissions, which is whether it is appropriate to assign responsibility for emissions to entities that extract and sell fossil fuels. Erickson and Lazarous 2013 illustrate how extraction-based emissions accounting can be contrasted to "territorial" and "consumption-based" accounting methods in the following figure:[282]

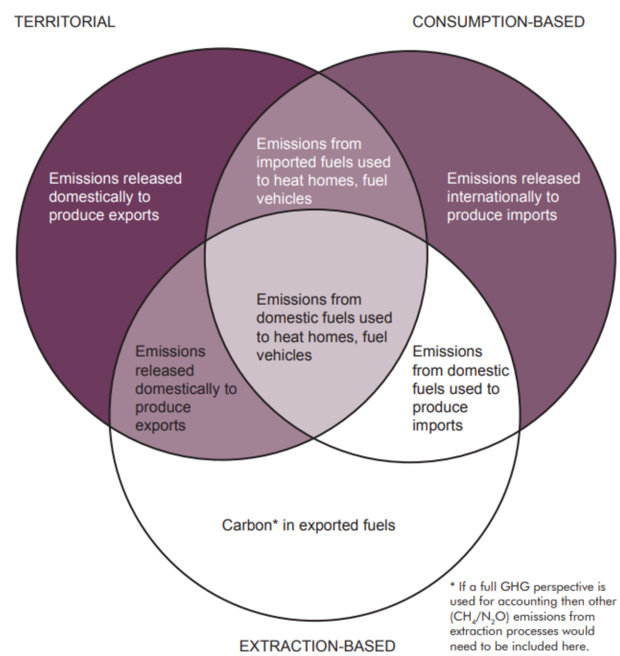

Figure 1: Comparison of territorial, consumption, and extraction-based GHG accounting

One might argue that imposing responsibly on upstream producers, or even midstream electric generators, is unfair because it lets consumers off the hook, but there are pragmatic and ethical

281. *See infra* Section III(C)(5) for an overview of cases filed against private actors for their contribution to climate change.

282. PETER ERICKSON & MICHAEL LAZARUS, STOCKLHOLM ENV'T INST., ACCOUNTING FOR GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE SUPPLY OF FOSSIL FUELS (2013).

reasons for focusing on upstream producers and electric generators. As a practical matter, it is easier to regulate a smaller group of well-informed companies than a very large group of poorly informed consumers, and some of the costs imposed on upstream and midstream entities will flow down to consumers, thus sending the appropriate price signals.[283] As an ethical matter, fossil fuel producers and energy companies have long known about the climate risks posed by use of their products, have lobbied against regulation, and ultimately profit most from the consumption of fossil fuels.

While most national emissions inventories currently focus on territorial emissions, researchers have found that it would be relatively easy for countries to produce extraction-based and consumption-based inventories based on readily available data.[284] In other words, pursuing these alternative accounting methodologies would not be significantly more expensive or technically challenging than the territorial approach. These alternative accounting methodologies also provide valuable insights that are not captured in the territorial approach—for example, the consumption-based approach accounts for "leakage" of GHG emissions to other countries via trade and helps countries understand the importance of developing policies aimed at reducing consumption of carbon-intensive products. Ultimately, though they may carry different legal weight, all three methodologies are useful in addressing the question of who is "responsible" for climate change.

283. *See, e.g.*, JONATHAN RAMSEUR & JANE LEGGETT, CONG. RES. SERV., R45625, ATTACHING A PRICE TO GREENHOUSE GAS EMISSIONS WITH A CARBON TAX OR EMISSIONS FEE: CONSIDERATIONS AND POTENTIAL IMPACTS (Mar. 22, 2019).

284. Glen P. Peters, *From Production-Based to Consumption-Based National Emissions Inventories*, 65 ECOLOGICAL ECONOMICS 13 (2008); Steven J. Davis & Ken Caldeira, *Consumption-Based Accounting of CO2 Emissions*, 107 PROC. NAT'L ACAD. SCI. 5687 (2010); Manfred Lenzen et al., *Building EORA: A Global Multi-Region Input–Output Database at High Country and Sector Resolution*, 25 ECON. SYS. RES. 20 (2013); Stavros Afionis et al., *Consumption-Based Carbon Accounting: Does It Have a Future?,* 8 WIREs CLIMATE CHANGE 1 (2017); Glen P. Peters, et al., *A Synthesis of Carbon in International Trade,* 9 BIOGEOSCIENCES 3247 (2012); Kirsten S. Wiebe & Norihiko Yamano, *Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015,* (OECD Sci., Tech. Indus., Working Paper 2016/05); Steven J. Davis et al., *The Supply Chain of CO2 Emissions*, 108 PROC. NAT'L ACAD. SCI. 18554 (2011); THOMAS MICHAEL POWER & DONOVAN S. POWER, THE ENERGY FOUNDATION, THE IMPACT OF POWDER RIVER BASIN COAL EXPORTS ON GLOBAL GREENHOUSE GAS EMISSIONS (2013).).

b. Status of Research

i. National Emissions Estimates

Countries have been developing and refining national greenhouse gas emission inventories since the early 1990s, pursuant to emission reporting requirements laid out in the United Nations Framework Convention on Climate Change (UNFCCC). The original agreement called upon developed countries (the "Annex I" parties) to prepare and periodically update national emission inventories listing all emissions and removals of direct GHGs from five sectors—energy; industrial processes and product use; agriculture; land use, land-use change, and forestry (LULUCF); and waste—in a standardized format.[285] The parties to the UNFCCC eventually introduced emission reporting requirements for non-Annex I countries as well, accompanied by programs aimed at addressing capacity and resource constraints in those countries.[286] The UNFCCC secretariat compiles all emissions inventory data in an online database,[287] and many other organizations use that data to analyze emissions trends.[288]

Due to this international emissions reporting system, there is a good deal of data on national emissions dating back to the 1990s, and the dataset has become more comprehensive through the 2000s as developed country parties have also begun reporting emissions. However, there are still significant gaps in the UNFCCC data, particularly with respect to historical emissions and developing country emissions through the mid-aughts. Governmental agencies, scientific organizations, and researchers have helped to fill gaps in UNFCCC data through independent

285. UNFCCC, Reporting Requirements, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/reporting-requirements [perma.cc/66SQ-5LNT] (last visited Sep. 11, 2019).

286. UNFCCC, *National Reports from Non-Annex I Parties*, UNITED NATIONS CLIMATE CHANGE, https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/national-communications-non-annex-i-parties/national-reports-from-non-annex-i-parties [https://perma.cc/P7E4-ZXAS] (last visited Sep. 11, 2019).

287. UNFCCC, *GHG Data from UNFCCC*, UNITED NATIONS CLIMATE CHANGE, https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/ghg-data-unfccc [https://perma.cc/Q7FD-EKQY] (last visited Sep. 11, 2019).

288. *See, e.g.*, *CAIT Climate Data Explorer*, WORLD RES. INST. http://cait.wri.org/ [https://perma.cc/K784-6M28] (last visited Dec. 30, 2019).

research on topics such as historical fossil fuel use by country,[289] but there is still a fair amount of uncertainty on national emissions estimates, especially prior to the 1990s.

The UNFCCC reporting approach focuses on emissions produced within a country. As noted above, another way to apportion emissions among countries is to focus on embedded emissions—that is, the emissions embedded within products consumed in the country. This more downstream approach to calculating national emissions has gained considerable traction in recent years. In 2010, researchers constructed a global database of CO_2 imports and exports.[290] The Global Carbon Project has since developed a similar database that looks at both domestically produced emissions ("CO_2 Production") and emissions once CO_2 embodied in both imports and exports have been included ("CO_2 Consumption").[291] Other research institutions have since published their own analyses of emissions embedded in trade products.[292] Some efforts have also been made to evaluate consumption-based emissions at sub-national levels.[293] Indeed, new approaches continue to emerge. For example, Matthews 2016 proposed and applied the notion of national carbon debts and credits, based on per capita cumulative emissions, relative to a benchmark.[294]

Several efforts have been made to link these national emissions to specific changes in climate and corresponding impacts. Li et al. 2016 focused on Chinese emissions and found that China

289. *See, e.g.*, *Carbon Dioxide Information Analysis Centre (CDIAC)*, U.S. DEPT. OF ENERGY, https://cdiac.ess-dive.lbl.gov/ [https://perma.cc/2W7H-HYZ7] (last visited Dec. 30, 2019); *ESS Dive*, U.S. DEP'T OF ENERGY, https://ess-dive.lbl.gov/ [https://perma.cc/5Y72-QV8L] (last visited Dec. 30, 2019); CAIT Climate Data Explorer, *supra* note 288; KEVIN A. BAUMERT ET AL., NAVIGATING THE NUMBERS: GREENHOUSE GAS DATA AND INTERNATIONAL CLIMATE CHANGE POLICY 3139 (2005); CLIMATE EQUITY REFERENCE CALCULATOR, https://calculator.climateequityreference.org/ [https://perma.cc/T5XU-89HM] (last visited Dec. 31, 2019).

290. Steven J. Davis et al., *The Supply Chain of CO2 Emissions*, 108 PROC. NAT'L ACAD. SCI. 18554 (2011).

291. *Global Carbon Budget,* GLOBAL CARBON PROJECT, https://www.globalcarbonproject.org/carbonbudget/ [https://perma.cc/Q8LU-92FE] (last visited Dec. 31, 2019). *See also* Glen Peters et al., *Growth in Emission Transfers Via International Trade from 1990 to 2008*, 108 PROC. NAT'L ACAD. SCI. 8903 (2011); Hausfather, *supra* note 50.

292. *See, e.g.*, Moran et al., *supra* note 50.

293. *See, e.g.*, C40 Cities, *supra* note 50.

294. H. Damon Matthews, *Quantifying Historical Carbon and Climate Debts Among Nations*, 6 NATURE CLIMATE CHANGE 60 (2016).

contributes 10 ± 4% of the current global radiative forcing, and that the relative contribution to global mean surface temperature (GMST) increase was 12 ± 2%.[295] Skeie et al. 2017 used a climate model to link the relative emissions contribution from multiple countries to GMST change, taking into account historical emissions and focusing on the largest emitters, and found that China was responsible for 6–13% and the United States was responsible for 15%–26% of the observed GMST increase.[296] Skeie et al. noted, however, that these findings were very sensitive to the parameters of the study, including technical decisions such as the timeframe for the analysis, as well as more normative decisions about the basis for attributing emissions (e.g., place of extraction vs. place of burning vs. place of final consumption) and about whether to look at per capita or total emissions. They also emphasized that, in non-linear systems, the proportional contribution to emissions will differ from the proportional contribution to impacts.

Otto et al. 2017 was the first study to apply the nation-based emissions framework to individual extreme event attribution, focusing on an Argentina heat wave.[297] A motivation was to quantify the proportional contribution of nation states to a phenomenon—specifically a damaging extreme event—that is closer to impacts and "losses" than phenomena to which source emission approaches had previously been applied, such as changes in global mean surface temperature.

The approach makes the simplifying assumption that each country's contributions to GMST can be linearly transferred to the Argentine heat wave. GMST is used as a responsibility indicator partly on the grounds that it is used in climate policy. Otto et al. uses two alternate methods to extract the relative contributions to GMST reported in Skeie et al., each of which has large uncertainties.[298] One major finding is that the sequence in which nations are summed in the cumulative approach is hugely important. It also means that when focusing on one entity's

295. Bengang Li et al., *The Contribution of China's Emissions to Global Climate Forcing*, 531 NATURE 357, 357 (2016).

296. Skeie et al., *supra* note 275.

297. Friederike E.L. Otto et al., *Assigning Historic Responsibility for Extreme Weather Events*, 7 NATURE CLIMATE CHANGE 757 (2017).

298. The distribution method assessed the US contribution as 34% (with a 20–54% uncertainty range), whereas the second approach, known as the gradient method, assessed the US at 28% (19–45% uncertainty range). *Id.* at 758.

emissions, results may be quite different if you remove the entity of interest from a full account, as opposed to adding that entity only to a counterfactual experiment. That is: the "How would the likelihood of the event change if only the region in question has emitted?" versus "How would the likelihood of the event change if the region of interest had not emitted?" questions yield very different results.

Finally, building on efforts to develop national emissions inventories and link these to climate change impacts, a fair amount of work has gone into developing "carbon budgets" both on a global level and for individual countries. Such budgets provide one possible foundation for holding governments accountable for mitigating their impact to climate change. The IPCC assessments and UNFCC targets (limiting warming to 2°C or 1.5°C) are, in turn, often used as the foundation for establishing budgets. Starting in the mid-aughts, the UNFCCC COP issued several decisions based on IPCC findings which recognize that industrialized countries must reduce emissions 25–40% below 1990 levels by 2020 to limit global warming to 2°C.[299] Academic researchers and organizations like the Global Carbon Project have since put a significant amount of work into developing more specific national budgets that correspond with the UNFCCC targets.[300] This work on carbon budgets is complemented by research examining the adequacy of national pledges under the Paris Agreement in light of temperature goals.[301]

299. *See, e.g.*, Bali Action Plan, U.N. DOC. FCCC/CP/2007/6/ Add.1; UNFCCC, Draft Resolution, Outcome of the Work of the Ad Hoc Working Group on Long-Term Cooperative Action under the Convention, Cancun, Mex. Nov. 29–Dec.10, 2010, U.N. DOC. FCCC/AWGLGA/2010/6.7 (Dec. 10, 2010); Report of the Conference of the Parties on its Eighteenth Session, held in Doha from 26 November to 8 December 2012, 2013; UNFCCC; FCCC/CP/2012/8, February 28, 2013.

300. *See, e.g.*, GLOBAL CARBON PROJECT, *supra* note 291.

301. *See, e.g.*, Yann Robiou de Pont & Malte Meinshausen, *Warming Assessment of the Bottom-Up Paris Agreement Emissions Pledges*, 9 NATURE COMMUNICATIONS 4810 (2018). Scholars from legal, policy, and social sciences disciplines have also written on the topic of how carbon budgets should be allocated to reflect normative considerations such as justice and equity, reflecting the fact that this is one area where the law and science interact in significant ways. *See, e.g.*, Cass Sunstein & Eric Posner, *Climate Change Justice* (John M. Olin Program in Law and Economics Working Paper No. 354, 2007); Catriona McKinnon, *Climate Justice in a Carbon Budget*, 133 CLIMATIC CHANGE 375 (2015).

ii. Corporate Emissions Estimates

There have been a number of efforts to attribute emissions to corporate actors and business sectors in recent years. Many of these efforts have focused on tracing emissions to the companies producing fossil fuels and other carbon-intensive products. Heede 2013 looked at historic production records from ninety producers of oil, natural gas, coal, and cement found that the emissions from these sources totaled 914 $GtCO_2e$, equivalent to 64% of cumulative worldwide emissions of industrial CO_2 and methane from 1751–2010.[302] Heede dubbed these producers the "carbon majors" based on their disproportionately large contribution to global emissions. He also found that approximately half of the emissions were generated since 1986—a piece of data which could be used to contradict claims about unforeseeability (since it is difficult to argue that companies were unaware of the risks of climate change by that time). Another noteworthy finding was that substantial emissions had come from fossil fuels sourced from non-Annex I countries such as China, India, Saudi Arabia, South Africa, Iran, Brazil, Mexico, Nigeria, Venezuela, Kuwait, Angola, Malaysia, and Libya, and that this called into question the UNFCCC's differential treatment of such countries at that time.[303] Heede's research eventually became the basis of the well-known *Carbon Majors* report, first published in 2014 and updated in 2017, and an accompanying online database.[304] Notably, the 2017 update found that one hundred fossil fuel producers were linked to 71% of industrial greenhouse gas emissions since 1988.[305]

Researchers from the Union of Concerned Scientists (UCS) have continued research on the carbon majors. Ekwurzel et al. 2017 took Heede's work a step further, applying his emission findings to a simplified climate model to assess the impacts of those emission contributions on global temperature change and sea level rise.[306]

302. Heede, *supra* note 31. These included fifty investor-owned, thirty-one state-owned, and nine nation-state producers of fossil fuels and cement. *Id.*

303. Heede, *supra* note 31, at 231.

304. RICHARD HEEDE, CARBON MAJORS: ACCOUNTING FOR CARBON AND METHANE EMISSIONS 1854–2010: METHODS & RESULTS REPORT (2014); PAUL GRIFFIN ET AL., THE CARBON MAJORS DATABASE: CDP CARBON MAJORS REPORT 2017 (2017); PAUL GRIFFIN ET AL., THE CARBON MAJORS DATABASE: METHODOLOGY REPORT 2017 (2017).

305. GRIFFIN ET AL., CDP CARBON MAJORS REPORT, *supra* note 304, at 8.

306. Ekwurzel et al., *supra* note 13. This approach was similar to that applied by Otto et al., *supra* note 297, insofar as the researchers went beyond merely estimating the

They found that emissions from the ninety carbon majors were responsible for approximately 57% of the observed rise in atmospheric CO_2, approximately 42–50% of the rise in global mean surface temperature (GMST), and 26–32% of the global sea level rise over the historical period from 1880–2010.[307] Taking a closer look at the past few decades, they find that the carbon majors were responsible for approximately 43% of the rise in atmospheric CO_2, 29–35% of the rise in GMST, and 11–14% of the global sea level rise from 1980–2010.[308]

These efforts have been complemented by initiatives such as the Climate Disclosure Project (CDP), a voluntary system whereby companies report on emissions in exchange for reputational credit,[309] as well as new legal mandates calling for companies to report emissions to national and in some cases sub-national governments.[310] The IPCC also compiles emissions data for specific sectors (energy, transport, buildings, industry, forestry, agriculture, and waste) and uses this data to help frame discussions on effective mitigation approaches.[311]

III. LEGAL AND POLICY APPLICATIONS

The ability to detect and attribute environmental changes to anthropogenic greenhouse gas emissions is useful for a variety of different law and policy applications. In the broadest sense, detection and attribution are the scientific tools that policy-makers and lawyers can use to show the existence, causes, and effects of

contribution of sources to global emissions and also looked at the effect on temperature change and sea level rise (whereas Otto et al. focused on an extreme event).

307. Ekwurzel et al., *supra* note 13, at 579.

308. *Id.* The authors note that the calculations are incomplete at this moment in time since the CO_2 already emitted will continue to impact the dependent climate variables in the future. Along similar lines, growing abatement of aerosol emissions associated with fossil fuel combustion leads to more warming and sea level rise per unit of fossil fuel combustion.

309. CLIMATE DISCLOSURE PROJECT (CDP), https://www.cdp.net [https://perma.cc/RA5A-K6VX] (last visited Sep. 11, 2019).

310. *See, e.g.*, *GHG Reporting Program,* EPA, https://www.epa.gov/ghgreporting [https://perma.cc/U42K-ZMAZ] (last visited Sep. 11, 2019); *Mandatory GHG Emissions Reporting,* CAL. AIR RES. BOARD, https://ww2.arb.ca.gov/our-work/programs/mandatory-greenhouse-gas-emissions-reporting [https://perma.cc/V32L-GG4H] (last visited Sep. 11, 2019).

311. *See* IPCC, WORKING GROUP III CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2014: MITIGATION OF CLIMATE CHANGE 351–413 (Ottmar Edenhofer et al. eds., 2014) (drawing most emissions data from the Emissions Database for Global Atmospheric Research (EDGAR) project).

climate change. This information can help inform critical policy decisions, such as the appropriate level for an emissions cap or a carbon tax. It can also help plaintiffs pursue certain types of legal actions, such as cases against government actors for failure to act on climate change. However, attribution science is not a panacea—the evidence generated by this field is not always effective at persuading or compelling policy-makers, courts, or the public to take action on climate change.[312] This is in part due to the complexity of and limitations in the science, but there are also barriers to policy and legal action on climate change that inhere in the nature of political decision-making and legal doctrine, unrelated to the quality of detection and attribution data.[313] This section addresses the salience of attribution science to policy-making at various scales of governance, its role in planning and environmental impact assessment, and the critical role it has played and will play in climate change litigation.

A. Policy-Making

Attribution science plays a critical role in policy-making. It helps to build support for actions to address the causes and impacts of climate change by: (i) demonstrating that anthropogenic climate change is already underway and resulting in adverse impacts, and (ii) lending confidence to model projections of how the climate will change in response to greenhouse gas emissions and how these changes will affect people and the environment in the decades to come.[314] Indeed, as the body of detection and attribution evidence has grown, an increasing number of jurisdictions have adopted greenhouse gas reduction targets and have commenced adaptation

312. *See, e.g.*, COMMUNICATING CLIMATE CHANGE INFORMATION FOR DECISION-MAKING (Silvio Serrao Neumann et al. eds, 2018); Ishani Mukherjee & Michael Howlett, *Communicating about Climate Change with Policymakers, in* OXFORD RESEARCH ENCYCLOPEDIA OF CLIMATE SCIENCE (2016); Sabrina McCormick et al., *Science in Litigation, the Third Branch of U.S. Climate Policy*, 357 SCIENCE 979, 979–980 (2017).

313. These include political, social, and economic barriers to policies and programs aimed at addressing climate change, as well as judicial doctrines that prevent courts from adjudicating climate change-related disputes. *See, e.g.*, Susanne C. Moser, *Communicating Climate Change: History, Challenges, Process and Future Directions*, 1 WIREs CLIMATE CHANGE 31 (2010); Richard J. Lazarus, *Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future*, 94 CORNELL L. REV. 1153 (2009).

314. Easterling et al., *supra* note 22.

planning activities.[315] The greater this body of evidence, the greater the justification for imposing stringent greenhouse gas reduction requirements, incentivizing the transition away from fossil fuels, and making large expenditures to prepare for the effects of climate change. Having a clear justification is important both for political reasons and for the purpose of defending mitigation and adaptation programs in court.

Attribution science can also contribute to more effective mitigation and adaptation policies. Information about source attribution is particularly helpful for informing mitigation policy, as it can be used to determine which actors, activities, or sectors should be targeted for regulation or to determine the appropriate level of regulation for any given source category. Meanwhile, information about impact attribution can help policy-makers identify the most significant climate change-related risks and make prudent decisions about how to allocate resources for adaptation.[316] For example, the IPCC, the USGCRP, and other authoritative bodies rely on quantitative detection and attribution studies to develop and refine their impact assessments, and this information feeds directly into national and sub-national adaptation planning efforts.[317] Regional modeling, downscaled analyses, and the use of local impact, adaptation, and vulnerability ("IAV") studies is particularly important in this context.

A related function of attribution science is that it can help decision-makers better understand the cost of unabated climate change, thus informing decisions about the appropriate level of regulation (e.g., the right price of a carbon tax) and also aiding in the justification of regulations. Consider the greenhouse gas emission and energy efficiency standards promulgated in the United States by the Obama Administration: for many of these

315. *See* Michal Nachmany & Joana Setzer, *Global Trends in Climate Change Legislation and Litigation: 2018 Snapshot,* GRANTHAM RES. INST. ON CLIMATE CHANGE & ENV'T, http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/04/Global-trends-in-climate-change-legislation-and-litigation-2018-snapshot-3.pdf [https://perma.cc/B672-822Q]; *Climate Change Laws of the World Database,* GRANTHAM RES. INST. ON CLIMATE CHANGE & ENV'T, http://www.lse.ac.uk/GranthamInstitute/climate-change-laws-of-the-world/ [https://perma.cc/HJ26-3U7A] (last visited Dec. 31, 2019).

316. *See* Easterling et al., *supra* note 22; Sebastian Sippel et al., *Stakeholder Perspectives on the Attribution of Extreme Weather Events: An Explorative Enquiry,* 7 WEATHER, CLIMATE, SOC'Y 224, 229 (2015).

317. *See* NCA4, *supra* note 7, at 114–32; IPCC AR5 WGI, *supra* note 25, at 867–952; IPCC AR5 WGII, *supra* note 18, at 979–1038.

rules, the U.S. Environmental Protection Agency ("EPA") conducted a cost-benefit analysis in which it monetized the effects of greenhouse gas emission reductions using the federal Social Cost of Carbon ("SC-CO_2")—a metric developed by the U.S. government that reflects the potential damages that can be attributed to the addition of one ton of CO_2 into the atmosphere in a particular year, expressed as a range of possible costs.[318] Using this metric, the Administration concluded that the total monetized benefits of the economic, environmental, and public health impacts from these standards significantly outweighed the costs.[319] This finding served as a key justification for issuing the standards.[320] While the SC-CO_2 and similar metrics for other gases are primarily based on predictions of future impacts, detection and attribution studies provide information about present impacts which can help to improve predictive models and also lend confidence to impact projections.

Finally, attribution science provides a framing mechanism for international negotiations, including those conducted under the United Nations Framework Convention on Climate Change ("UNFCCC") and the Paris Agreement. There are several ways in which attribution science is useful in this context. First, the growing body of evidence linking emissions and land use changes to harmful impacts helps build political support for ambitious action on climate change, and also provides a basis for critiquing countries that do not go far enough with their emission reduction pledges (referred to in the Paris Agreement as "nationally determined contributions").[321] Second, attribution science can

318. *See, e.g.*, EPA, EPA-452-R-15-003, REGULATORY IMPACT ANALYSIS FOR THE CLEAN POWER PLAN FINAL RULE (Aug. 2015); EPA, EPA-420-R-12-016, REGULATORY IMPACT ANALYSIS: FINAL RULEMAKING FOR 2017–2025 LIGHT-DUTY VEHICLE GREENHOUSE GAS EMISSION STANDARDS AND CORPORATE AVERAGE FUEL ECONOMY STANDARDS (Aug. 2012); Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment Final Rule, 79 Fed. Reg. 17,726 (Mar. 28, 2014) (codified at 10 C.F.R. pt. 431(c)).

319. Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment Final Rule, 79 Fed. Reg. at 17,730.

320. Zero Zone Inc. v. Dep't of Energy, 832 F.3d 654, 678–79 (7th Cir. 2016) (upholding use of the SC-CO_2 in rulemaking establishing energy conservation standards for commercial refrigeration equipment).

321. Paris Agreement, *supra* note 280, at art. 14, ¶ 1 (establishing a "global stocktake" whereby the parties to the agreement "shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals."). For information about how emission budgets would

help improve decision-making about how to allocate funds for adaptation insofar as it provides insight into which countries, regions, sectors, and population groups have the greatest risk of harm due to anthropogenic climate change. Third, attribution science can help countries reach agreement on the highly contentious "loss and damage" framework whereby the countries that are least responsible for climate change are compensated by more responsible countries for harmful impacts caused by climate change.[322]

This third area—loss and damage—is where attribution science could potentially play the biggest role. To develop a functional loss and damage framework, countries would need to answer two types of questions that can only be answered through a combination of attribution science and predictive modeling: first, which countries have already suffered harmful impacts as a result of climate change and are most certain to do so in the future, and second, to what extent are other countries responsible for those impacts.[323] As discussed above, one complicating factor is that there are often multiple drivers behind harmful impacts linked to climate change—for example, construction and development practices within a coastal community can increase the vulnerability of people and structures in that area to the effects of storms and sea level rise, and numerous factors, including degree of community cohesion and economic development, can decrease resilience to them. In

serve as benchmarks in the global stocktake, *see generally* Christian Holz & Xolisa Ngwadla, *The Global Stocktake Under the Paris Agreement: Opportunities and Challenge*, EUROPEAN CAPACITY BUILDING INITIATIVE (Anju Sharma ed., 2016), http://www.eurocapacity.org/downloads/GST_2016%5B1%5D.pdf [https://perma.cc/ER2Y-DGKE]; *see also* IPCC, SPECIAL REPORT: GLOBAL WARMING OF 1.5°C (Valerie Masson-Delmotte et al. eds., 2018), https://www.ipcc.ch/sr15/ [https://perma.cc/9959-GSRB] (providing a recent example of how information about climate change impacts can build considerable political support for climate action).

322. For more on this topic, see Christian Huggel et al., Commentary, *Loss and Damage Attribution*, 3 NATURE CLIMATE CHANGE 694 (2013); Rachel James et al., *Characterizing Loss and Damage From Climate Change*, 4 NATURE CLIMATE CHANGE 938 (2014); Daniel Farber, *The Case for Climate Compensation: Justice for Climate Change Victims in a Complex World*, 2008 UTAH L. REV. 377 (2008).

323. For a more detailed discussion of how attribution science can inform the development of a loss and damage framework, *see* Christian Huggel et al., *Reconciling Justice and Attribution Research to Advance Climate Policy,* 6 NATURE CLIMATE CHANGE 901 (2016); Roda Verheyen, *Loss and Damage Due to Climate Change: Attribution and Causation—Where Climate Science and Law Meet*, 8 INT'L J. GLOBAL WARMING 158 (2015); Christian Huggel et al., *Potential and Limitations of the Attribution of Climate Change Impacts For Informing Loss and Damage Discussions and Policies,* CLIMATIC CHANGE (SPECIAL ISSUE) 10.1007 (2015).

most cases, even the most sophisticated attribution studies cannot fully resolve the question of how much of the harm incurred by a community is due to anthropogenic climate change as opposed to confounding risk factors. The complex and multi-causal nature of harms related to climate change may therefore make it difficult to reach consensus on loss and damage issues. As discussed in further detail below, it may also prove to be an obstacle to lawsuits seeking compensation from emitters for climate-related damages.

B. Planning and Environmental Impact Assessment

Attribution science also facilitates on-the-ground planning for the effects of climate change by providing more robust data about how climate change is already affecting landscapes, ecosystems, and human systems such as cities, infrastructure, and food production. This information can feed into scenario planning, informing the likely and possible ranges of outcomes under different greenhouse gas emission trajectories.[324] Finally, attribution studies that focus on regional or localized impacts can be used to develop and refine downscaled projections of climate change impacts within a particular geographic region, and to improve the accuracy and precision of the models that are used to develop those projections.[325] All of this can feed into a more robust analysis of how climate change is affecting and will affect proposed and planned actions.

We see this type of analysis being performed in regional resource management planning, state and local planning, environmental reviews, and corporate disclosures. For example, during the Obama Administration, the federal agencies that manage public lands and natural resources began using detection and attribution science to better understand how climate change is affecting water

324. Easterling et al., *supra* note 22. *See generally Observed and Projected (Longer-term) Changes in Weather and Climate Extremes,* 11 WEATHER CLIMATE EXTREMES (SPECIAL ISSUE) A1 (2016).

325. *See, e.g.*, Mohammad Reza Najafi et al., *Attribution of the Observed Spring Snowpack Decline in British Columbia to Anthropogenic Climate Change,* 30 J. CLIMATE 4113 1 (2017); Beena Balan Sarojini et al., *Detection and Attribution of Human Influence on Regional Precipitation,* 6 NATURE CLIMATE CHANGE 669 (2016); Peihua Qin & Zhenghui Xie, *Detecting Changes in Future Precipitation Extremes Over Eight River Basins in China Using RegCM4 Downscaling,* 121 J. GEOPHYSICAL RES. ATMOSPHERES 6802 (2016); Chunzhen Liu & Jun Xia, *Detection and Attribution of Observed Changes in the Hydrological Cycle under Global Warming,* 2 ADVANCES IN CLIMATE CHANGE RES. 31 (2011); Tim P. Barnett et al., *supra* note 239, at 1080.

resources, ecosystems, and biodiversity in the United States and to develop appropriate response strategies.[326] Federal, state, and local agencies are also now using data on observed impacts such as sea level rise, melting permafrost, and extreme heat events to better understand natural hazards and to inform planning decisions.[327]

Attribution science can also help decision-makers better understand a proposed or planned action's contribution to global climate change. Currently, environmental impact assessments ("EIAs") and other planning documents express this contribution by quantifying the anticipated greenhouse gas emissions that will be generated as a result of the action, and then providing a brief qualitative description of the types of impacts which can be expected as a result of climate change. Because the overall contribution of the action to global greenhouse gases is typically quite small, no attempt is made to draw a direct link between the action's greenhouse gas emissions and specific on-the-ground impacts of climate change. Improvements in detection and attribution could facilitate the development and refinement of metrics that could be used to better explain how a project will contribute to global climate change. The SC-CO_2 and cost metrics for nitrous oxide ("SC-N_2O") and methane ("SC-CH_4") are good examples: EIA documents can use these metrics to translate greenhouse gas emissions into a specific dollar value which serves as a proxy for on-the-ground impacts (and as discussed above,

326. *See, e.g.*, PETER BACKLUND ET AL., U.S. CLIMATE CHANGE SCI. PROGRAM, THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE, LAND RESOURCES, WATER RESOURCES, WATER RESOURCES, AND BIODIVERSITY IN THE UNITED STATES (Margaret Walsh et al. eds., 2008); LEVI D. BREKKE, U.S. GEOLOGICAL SUR., CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT: A FEDERAL PERSPECTIVE, CIRCULAR 1331 (2009); JESSICA WENTZ, SABIN CTR. FOR CLIMATE CHANGE L., CONSIDERING THE EFFECTS OF CLIMATE CHANGE ON NATURAL RESOURCES IN ENVIRONMENTAL REVIEW AND PLANNING DOCUMENTS: GUIDANCE FOR AGENCIES AND PRACTITIONERS (2016).

327. *See, e.g.*, *Sea Level Rise,* CAL. ADAPT., https://cal-adapt.org/tools/slr-calflod-3d/ [https://perma.cc/5BQD-2EJL] (last visited Sep. 11, 2019); Press Release, NYS Dep't of Envt'l Conservation, DEC Announces New Sea Level Rise Projection Regulation for New York (Feb. 6, 2017), http://www.dec.ny.gov/press/109195.html [https://perma.cc/7XAY-BZWJ]; *Sea Level Rise Viewer,* NOAA, https://coast.noaa.gov/slr/ [https://perma.cc/X48G-QFBT] (last visited Nov. 21, 2019); *Flood Map Revision Process,* FEMA, https://www.fema.gov/flood-map-revision-processes [https://perma.cc/YZQ5-CU5A] (last visited Nov. 21, 2019). *See also* ADITI KAPOOR, CLIMATE DEVELOPMENT KNOWLEDGE NETWORK AND WORLD WEATHER, POLICY BRIEF: CLIMATE ATTRIBUTION SCIENCE: A USEFUL TOOL TO PLAN FOR EXTREME HEAT EVENTS (2017).

improved attribution data can be used to justify and refine these metrics).

C. Litigation

Evidence linking human influence on climate to the harmful impacts of climate change plays an important role in lawsuits seeking to compel action on climate change as well as the legal defense of programs and regulations aimed at reducing greenhouse gas emissions or advancing adaptation objectives. The manner in which such evidence is utilized and the extent to which it influences case outcomes will depend on the type of case and the stage of litigation. Below, we present a detailed breakdown of legal issues and cases involving climate change-related claims and how attribution science is used in different contexts: 1) establishing standing to sue; 2) introducing expert scientific testimony and reports as evidence; 3) challenges to government failures to regulate GHG emissions; 4) the legal defense of existing GHG emission standards; 5) lawsuits seeking to hold emitters liable for damages from climate change impacts; and 6) lawsuits involving climate change adaptation, impact assessment, and disclosures.[328]

1. Establishing Standing to Sue Sources of GHG Emissions for Climate-Related Harms

Standing doctrines address the question of who should have access to courts to adjudicate a particular claim.[329] Whether a plaintiff has standing is a jurisdictional question that is addressed at

328. There are certain legal doctrines that may control the outcome of these cases but more indirectly implicate questions of attribution, such as the political question doctrine, the foreign affairs preemption doctrine, and the doctrine of legislative displacement. *See* discussion *infra* Section III(C)(5).

329. There is large body of scholarship on the question of standing for climate change-related damages. *See, e.g.*, Bradford C. Mank, *Standing and Future Generations: Does* Massachusetts v. EPA *Open Standing for Generations to Come?*, 34 COLUM. J. ENVTL. L. 1 (2009); Bradford C. Mank, *Standing and Global Warming: Is Injury to All Injury to None?*, 35 ENVTL. L. 1 (2005); Blake R. Bertagna, Comment, *"Standing" Up for the Environment: The Ability of Plaintiffs to Establish Legal Standing to Redress Injuries Caused by Global Warming*, 2006 BYU L. REV. 415 (2006); Christopher L. Muehlberger, Comment, *One Man's Conjecture is Another Man's Concrete: Applying the "Injury-in-Fact" Standing Requirement to Global Warming*, 76 UMKC L. REV. 177 (2007); Joseph M. Stancati, Note, *Victims of Climate Change and Their Standing to Sue: Why the Northern District of California Got it Right*, 38 CASE W. RES. J. INT'L L. 687 (2006–2007); Nigel Cooney, Note, *Without a Leg to Stand on: The Merger of Article III Standing and Merits in Environmental Cases*, 23 WASH. U. J. L. & POL'Y 175 (2007).

the outset of litigation before the merits are adjudicated.[330] Standing requirements vary considerably by jurisdiction. Here, we will focus on the standing jurisprudence of U.S. federal courts—since this is the context where attribution science has played the most significant role—recognizing that these federal standards are among the most restrictive in the world.[331]

Federal standing doctrine arises from the Supreme Court's determination that Article III of the Constitution limits the jurisdiction of the federal courts to cases or controversies where the plaintiff has a concrete and personal stake in the outcome of the litigation.[332] Based on this understanding, the Supreme Court has held that Plaintiffs must establish that (i) they have suffered an injury-in-fact—that is, "an invasion of a legally protected interest which is (a) concrete and particularized and (b) actual or imminent, not conjectural or hypothetical;"[333] (ii) the injury-in-fact is fairly traceable to the defendants' allegedly unlawful actions;[334] and (iii) the injury could be redressed by a favorable court decision.[335] Attribution science is central to standing contests over each of these prongs.

a. Standing Elements

i. Injury-in-Fact

The types of harms giving rise to standing include injuries to economic, physical, spiritual, aesthetic, and recreational interests.[336] There is no threshold requirement for the size of the

330. While standing is a jurisdictional issue, the issues implicated in the standing analysis may go directly to the merits of the case, which may lead a court to defer its standing analysis under the case has been fully briefed and all evidence reviewed.

331. *See* John Dimanno, *Beyond Taxpayers' Suits: Public Interest Standing in the States*, 41 CONN. L. REV. 639 (2008); Christopher S. Elmendorf, *State Courts, Citizen Suits, and the Enforcement of Federal Environmental Law by Non-Article III Plaintiffs*, 110 YALE L.J. 1003 (2001); J. Michael Angstadt, *Securing Access to Justice Through Environmental Courts and Tribunals: A Case in Diversity,* 17 VT. J. ENVTL. L. 345 (2016); Matt Handley, *Why Crocodiles, Elephants, and American Citizens Should Prefer Foreign Courts: A Comparative Analysis of Standing to Sue*, 21 REV. LITIG. 97, 117 (2002); Niran Somasundaram, *State Court Solutions: Finding Standing for Private Climate Change Plaintiffs in the Wake of* Washington Environmental Council v. Bellon, 42 ECOLOGY L.Q. 491 (2015).

332. Lujan v. Defs. of Wildlife, 504 U.S. 555, 556 (1992).

333. *Id.* at 560 (internal citations and quotations omitted).

334. *Id.*

335. *Id.* at 561.

336. Ass'n of Data Processing Serv. Orgs. Inc. v. Camp, 397 U.S. 150, 152, 154 (1970).

injury—any "identifiable trifle" is sufficient to establish standing.[337] However, injury must be "particularized," meaning that it is not a "generalized grievance" shared by the public at large.[338] The requirement of particularized injury has been viewed as a potential barrier for plaintiffs seeking standing based on injuries caused by climate change, since such injuries are often shared by the public. However, some plaintiffs have successfully used impact attribution research to persuade the courts that their injuries are sufficiently particularized for standing purposes.[339]

It is more difficult to establish an injury-in-fact based on the risk of future harm. The general rule is that the future harm must be "imminent, not conjectural or hypothetical."[340] The term can be interpreted as entailing a temporal element, a probabilistic element, or both.[341] The Supreme Court has conceded that this is an "elastic concept"[342] and has defined it differently in different cases. Most recently, the Court has held that the imminence requirement is met where the harm is "certainly impending" or where there is a "substantial risk" of the harm occurring.[343] To establish standing based on the prospect of future environmental damage, plaintiffs must demonstrate either: (i) a substantial risk of direct harm (e.g., physical health impacts), or (ii) that they visit the affected area or use the affected resources for recreational, spiritual, or aesthetic purposes and/or have concrete plans to do so in the future.[344]

337. United States v. Students Challenging Regulatory Agency Procedures (SCRAP), 412 U.S. 669, 689 n.14 (1973).

338. United States v. Richardson, 418 U.S. 166, 171 (1974); Schlesinger v. Reservists Comm. To Stop the War, 418 U.S. 208, 217 (1974).

339. *See* Massachusetts v. EPA, 549 U.S. 497, 525 (2007) (finding state had standing due to loss of land resulting from sea level rise), Connecticut v. Am. Elec. Power Co., 582 F.3d 309 (2d Cir. 2009*), rev'd*, 564 U.S. 410 (2011) (finding state had standing due to loss of snow pack, the corresponding effect on water supplies and flooding, and the effect of sea level rise and coastal erosion on coastal property).

340. *Lujan*, 504 U.S. at 560.

341. Evan Tsen Lee & Josephine Mason Ellis, *The Standing Doctrine's Dirty Little Secret*, 107 NW. U.L. REV.169, 179–80 (2012) (noting cases where courts have found a lack of imminence because the alleged injury would not happen immediately, and cases where courts have found a lack of imminence because the injury was too "conjectural" and there was insufficient probability that it would ever occur).

342. *Lujan,* 504 U.S. at 565 n.2.

343. Clapper v. Amnesty Int'l USA, 568 U.S. 398, 414 n.5 (2013); Susan B. Anthony List v. Driehaus, 573 U.S. 149, 158 (2014).

344. *Lujan*, 504 U.S. 555; Summers v. Earth Island Inst., 555 U.S. 488 (2009).

ii. Causation and Redressability

The second and third elements of standing (causation and redressability) are closely related, sometimes referred to as "two sides of the same coin."[345] These requirements have proven to be the most difficult to prove in cases involving climate-related harms. For causation, the plaintiff must establish that the injury is "fairly traceable" to the challenged action "and not the result of the independent action of some third party not before the court."[346] Courts often look for factual causation, typically expressed as a "but for" test: would the plaintiff not have been injured but for the defendant's action.[347] In cases brought against governments and private actors for failure to regulate or abate emissions, the Supreme Court has found sufficient causation where the emissions represent a "meaningful contribution" to global climate change.[348] What constitutes a "meaningful contribution" to global climate change is a question that at this point will be determined on a case-by-case basis.[349]

Finally, the redressability prong requires that it is likely and not "merely speculative" that the injury would be redressed by a favorable decision.[350] The prospect of even partial redress may be sufficient.[351]

345. Ctr. For Biological Diversity v. EPA, 90 F. Supp. 3d 1177, 1190 (W.D. Wash. 2015). *See also* Gonzales v. Gorsuch, 688 F.2d 1263, 1267 (9th Cir. 1982); Duke Power Co. v. Carolina Envtl. Study Grp., 438 U.S. 59, 74 (1978).

346. *Lujan*, 504 U.S.at 560 (internal citations and quotation marks omitted).

347. *See, e.g., Duke Power Co*, 438 U.S. at 74–75; Allen v. Wright, 468 U.S. 737, 758 (1984).

348. *See Massachusetts*, 549 U.S. at 525 (emissions from all U.S. motor vehicles made a "meaningful contribution" to global climate change).

349. *See, e.g.*, Wash. Envtl. Council v. Bellon, 732 F.3d 1131, 1135 (9th Cir. 2013) (emissions from Washington power plants amounting to 6% of state's total GHG emissions not a "meaningful contribution" to climate change), *reh'g en banc denied*, 741 F.3d 1075 (9th Cir. 2014); Amigos Bravos v. U.S. Bureau of Land Mgmt., 816 F. Supp. 2d 1118, 1136 (D.N.M. 2011) (254,730 metric tons of GHGs per year that might result from the approval of 92 oil and gas leases were not a "meaningful contribution" to global climate change); Juliana v. United States, 217 F. Supp. 3d 1224 (D. Or. 2016) (Motion to Dismiss denied because U.S. agencies had regulatory authority over at least 14% of global GHGs and this was sufficient for standing).

350. *Lujan*, 504 U.S. at 561.

351. *See Massachusetts*, 549 U.S. 497; *Am. Elec. Power Co.*, 582 F.3d 309 (2d Cir. 2009), *rev'd*, 564 U.S. 410 (2011).

iii. Procedural Injury

Standing requirements are somewhat relaxed for cases that involve "procedural injuries."[352] Such injuries occur when agencies undertake actions without adhering to legally mandated procedures, such as when a federal agency undertakes a major action without preparing an environmental impact statement ("EIS"), promulgates a final rule without adhering to the Administrative Procedure Act ("APA")'s notice and comment requirements, or otherwise fails to implement a process that is required by statute.[353] Courts will sometimes refer to these cases as involving "procedural rights."[354]

iv. Standing for States and Associations

Adding an additional layer to the standing analysis is the fact that states have special standing to sue, both by virtue of their sovereign status and the breadth of their interests, which encompass the state's direct interests, e.g., state property, as well as the interests of their residents.[355] Large associations may also have an easier time establishing standing than private individuals due to the number of members in those associations. This holds true in cases involving the risk of future harm: an association with many members may be able to establish that, in aggregate, its members face a "substantial

352. *Lujan*, 504 U.S. at 571–72.

353. Christopher T. Burt, Comment, *Procedural Injury Standing After* Lujan v. Defenders of Wildlife, 62 U. CHI. L. REV. 275, 276 (1994); F. Andrew Hessick, *Probabilistic Standing*, 106 NW. U. L. REV. 55, 69 (2012) (citing *Summers*, 555 U.S. at 496–97).

354. *Lujan*, 504 U.S. at 572 n.7; *Massachusetts*, 549 U.S. at 498 (citing APA § 7607(b)(1)) (noting that that the "right to challenge agency action unlawfully withheld" is a procedural right created by the APA). In *Lujan*, the Supreme Court affirmed that procedural rights are "special" and that "[t]he person who has been accorded a procedural right to protect his concrete interests can assert that right without meeting all the normal standards for redressability and immediacy." 504 U.S. at 572 n.7. The Court further explained, "Thus, under our case law, one living adjacent to the site for proposed construction of a federally licensed dam has standing to challenge the licensing agency's failure to prepare an environmental impact statement, even though he cannot establish with any certainty that the statement will cause the license to be withheld or altered, and even though the dam will not be completed for many years." *Id.* Notably, the plaintiff must still show that they will suffer a concrete injury-in-fact that is linked to the procedural injury. *Summers*, 555 U.S. at 496 (citing *Lujan*, 504 U.S. at 572 n. 7); *Massachusetts*, 549 U.S. at 518 (noting that the plaintiff needs to show that the "procedural step was connected to the substantive result" and that there is "some possibility that the requested relief will prompt the injury-causing party to reconsider the decision that allegedly harmed the litigant."). For more on this topic, see Burt, *supra* note 353, at 280–81.

355. *Massachusetts*, 549 U.S. 497; Georgia v. Tenn. Copper Co., 237 U.S. 474 (1915).

risk" of harm, where an individual plaintiff would not be able to make this showing.

Consider the case of *Natural Resources Defense Council v. EPA*, a case involving a challenge to the adequacy of an ozone pollution standard decided by the D.C. Circuit Court of Appeals in 2007. The ozone standard was expected to result in a very small increase in the risk of cancer—one in 200,000, according to NRDC's experts. This might not have sufficed as an "imminent" threat to an individual plaintiff's interest, but NRDC was able to establish standing by presenting evidence of the aggregated risk across all of its 490,000 members.[356] The D.C. Circuit Court of Appeals explained:

> The lifetime risk that an individual will develop nonfatal skin cancer as a result of EPA's rule is about 1 in 200,000 by the intervenor's lights. Even if a quantitative approach is appropriate—an issue on which we express no opinion—this risk is sufficient to support standing. One may infer from the statistical analysis that two to four of NRDC's nearly half a million members will develop cancer as a result of the rule.[357]

However, in *Summers v. Earth Island Inst.*, five Supreme Court justices rejected a similar argument in the public lands context. There, the Sierra Club sought standing to challenge U.S. Forest Service regulations based on potential injury to its members' use and enjoyment of national forests. The majority denied standing because the Sierra Club had failed to establish that any member had concrete plans to visit a site where the regulations would be applied.[358] The dissent argued that, because the Sierra Club had 700,000 members, there was a statistical probability that one of their members would be adversely affected by the regulations,[359] but the majority held that "such speculation does not suffice" for standing purposes.[360]

356. Nat. Res. Def. Council v. EPA, 464 F.3d 1, 7 (D.C. Cir. 2006).

357. *Id.*

358. *Summers*, 555 U.S. at 496.

359. *Id.* at 505–07.

360. *Id.* at 499. *Summers* does not totally foreclose the possibility of standing based on a probabilistic injury. The probabilistic inquiry in *Summers* was whether one of the association members might visit a forest that was affected by the regulation in the near future—this question is much easier to answer through affidavits than through statistical analysis, since it depends on the members' intent. In contrast, the probabilistic inquiry in *Nat. Res. Def.*

v. Concluding Notes on Standing

As may be evident from the above discussion, standing jurisprudence is viewed by many as "incoherent"[361] and inevitably subjective.[362] The lack of a coherent approach is particularly apparent in cases involving the risk of future harm, where courts typically conduct a qualitative rather than quantitative assessment of the risk to determine whether it rises to a level of imminence.[363] Hessick notes that as a likely consequence of their qualitative analyses, courts have "[g]enerally proven themselves incapable of applying [this standard] in a rigorous way,"[364] and explains that "[u]ncertainty about probability forces courts to forego precise calculations of probabilities and instead to evaluate probability on a gestalt feeling of the likelihood of a harm occurring. Assessments of this sort, however, are vulnerable to biases."[365] As a result of these factors, it is very difficult to predict whether or how federal courts will grant standing in climate change cases, particularly where plaintiffs allege an increased risk of future harm rather than a present injury. One way or the other, the state of attribution science is and will be central.

b. Case Law on Standing to Sue for Climate Change-Related Harms

The role of attribution science in establishing standing, then, is to determine whether plaintiffs have suffered an injury, or risk of an injury, that can be linked to anthropogenic climate change, and therefore linked to emissions that were generated by a private entity or inadequately regulated by a government entity. Attribution data is a valuable complement to impact projections as it can be used to establish an existing injury while also lending

Council v. EPA was whether one of the association members might be harmed by involuntary exposure to pollution—statistical analysis is both necessary and well-suited to making such predictions. Faced with a situation more analogous to *Nat. Res. Def. Council v. EPA,* the Court may have reached a different conclusion about the statistical probability of injury.

361. Lee & Ellis, *supra* note 341, at 169, 200; William A. Fletcher, *The Structure of Standing,* 98 YALE L. J. 221, 231 (1988).

362. Cass Sunstein, *What's Standing After Lujan? Of Citizen Suits, "Injuries," and Article III,* 91 MICH. L. REV. 163, 188–89 (1992); Albert Lin, *The Unifying Role of Harm in Environmental Law,* 3 WIS. L. REV. 897, 938 (2006); Lee & Ellis, *supra* note 341, at 200; Hessick, *supra* note 353, at 73.

363. Hessick *supra* note 353, at 73.

364. *Id.*

365. *Id.* at 75.

credibility to projections of future harm. This section reviews key decisions which illustrate how attribution of impacts to anthropogenic climate change factors into standing analysis.

i. *Massachusetts v. EPA*

The Supreme Court first addressed the issue of standing to bring climate change-related claims in *Massachusetts v. EPA*. There, a group of states, cities, and environmental organizations brought a lawsuit challenging the EPA's decision not to regulate greenhouse gas emissions from motor vehicles under the Clean Air Act. One of the key questions in the case was whether EPA could decline to exercise its regulatory authority because there was too much uncertainty about the causes and effects of climate change.[366] The question of uncertainty was also relevant to the question of standing—the issue being whether plaintiffs could establish a sufficiently certain causal link between the failure to regulate and harms that they had incurred and would incur as a result of climate change. Because this case involved a procedural right—specifically, the right to challenge agency action unlawfully withheld—the immediacy and redressability requirements were relaxed.[367]

In their briefs, the plaintiffs supported their standing and merits claims by describing the many harms that they would incur as a result of climate change—for example, the states were experiencing and would continue to experience a "loss of state-owned property to rising sea levels. . . added costs to deal with emergency response measures caused by more frequent intense storm surge flooding events . . . damage to state-owned historic, archeological, and natural resources including state forests . . . [and] damage to state-owned facilities and infrastructure along the coast."[368] These assertions were supported by numerous

366. *Massachusetts*, 549 U.S. at 497, 513–14 (citing EPA, Control of Emissions from New Highway Vehicles and Engines: Notice of Denial of Petition for Rulemaking, 68 Fed. Reg. 52922, 52929–31 (Sept. 8, 2003)).

367. *Id.* at 518.

368. Petitioners' Reply Brief in Support of Petition for Mandamus at 2, Massachusetts v. EPA, 549 U.S. 497 (2007) (No. 05-1120).

expert declarations[369] as well as an amicus brief filed by climate scientists in support of the plaintiffs.[370]

In its initial review of the case, the U.S. Court of Appeals for the D.C. Circuit proceeded directly to the merits without resolving the standing issues separately, noting that this was a case where the standing inquiry and the merits inquiry clearly overlapped and that it would be "exceedingly artificial to draw a distinction between the two."[371] One concurring judge commented on standing, asserting that he would have dismissed the case because the plaintiffs only alleged what he viewed as a "generalized grievance" shared by all U.S. residents rather than the sort of "particularized grievance" required under standing law.[372]

On review, a five justice majority held that at least one of the plaintiffs—the state of Massachusetts—had presented sufficient evidence of actual and imminent harms to establish standing in the case, specifically the fact that it would suffer serious loss of coastal property as a result of sea level rise.[373] The Court noted that Massachusetts had a "special position and interest" in the case, in part because "it actually owns a great deal of the territory alleged to be affected" by climate change, and in part because of its status as a sovereign state.[374] The Court referred to data in the petitioners' affidavits showing that "global sea levels rose between 10 and 20 centimeters over the 20th century as a result of global warming and have already begun to swallow Massachusetts' coastal land" and that "[r]emediation costs alone . . . could reach hundreds of millions of dollars."[375] It held that this was a sufficiently particularized injury. Responding to EPA's assertion that Massachusetts' injury was "conjectural because the land loss that the state expected could not be quantified," the Court said that it was unnecessary to determine "the precise metes and bounds of [the state's] soon-to-be-flooded

369. *See, e.g.*, Final Brief for the Petitioners at 2–3, Massachusetts v. EPA, 415 F.3d 50 (D.C. Cir. 2005) (Nos. 03-1361, consolidated with Nos. 03-1362 through 03-1368).

370. Brief of Amici Curiae Climate Scientists David Battisti, et. al. in Support of Petitioners at 10–18, Massachusetts v. EPA, 549 U.S. 497 (2007) (No. 05-1120).

371. Massachusetts v. EPA, 415 F.3d 50, 56 (D.C. Cir. 2005), *rev'd*, 549 U.S. 497 (2007). Interestingly, on the merits the court held that there was sufficient uncertainty about the causes and effects of climate change such that EPA had reasonably declined to exercise its authority. *Massachusetts*, 415 F.3d at 58.

372. *Id.* at 60–61 (Sentelle, J., concurring).

373. *Massachusetts*, 549 U.S. at 517.

374. *Id.* at 523.

375. *Id.* at 521–23.

land" because the general trend was clear: Massachusetts was losing land and would continue to lose land to sea level rise.[376]

Turning to the causation and redressability prongs of standing, the court rejected EPA's assertion that its decision not to regulate would contribute "so insignificantly to petitioners' injuries" and thus there was "no realistic possibility that the relief sought would . . . remedy petitioners' injuries, especially since predicted increases in emissions from China, India, and other developing nations will likely offset any marginal domestic decrease EPA regulation could bring about."[377] First, the Court noted that, judged by any standard, U.S. motor vehicle emissions make a "meaningful contribution" to greenhouse gas concentrations and global warming (in 1999, they accounted for more than 6% of worldwide carbon dioxide emissions, or 1.7 billion metric tons).[378] The Court acknowledged that EPA could not by itself reverse global warming through motor vehicle standards but this did not mean that the court lacked jurisdiction to decide "whether EPA has a duty to take steps to *slow* or *reduce* it."[379] The majority explained that while a favorable decision would not totally remedy the problem, Massachusetts would not lose as much land as it otherwise would.[380] Thus, the majority treated redressability "as a matter of degree rather than an all-or-nothing proposition."[381]

ii. *Connecticut v. American Electric Power Company*

In subsequent cases, federal courts have raised questions about whether to grant standing to petitioners who are: (i) not states (and therefore have fewer interests of a different nature that could be affected by climate change), (ii) seeking regulation of emission sources with a much smaller greenhouse gas footprint than the U.S. motor vehicle fleet, or (iii) not alleging a procedural injury.

Connecticut v. American Electric Power Company was a case that involved state plaintiffs but lacked a procedural injury claim. There, a group of state, city, and non-governmental plaintiffs sued five power companies, alleging that their contribution to climate

376. *Id.* at 523, n.21.
377. *Id.* at 523–24.
378. *Id.* at 525.
379. *Id.* at 525.
380. *Id.* at 525–26.
381. Lee & Ellis, *supra* note 341, at 192.

change constituted a public nuisance under both federal and state common law. The plaintiffs alleged a combination of existing and future injuries associated with climate change. For example, the states cited studies showing that climate change was already causing sea level rise and snowpack melt and that this had an adverse effect on their interests and their residents.[382]

The U.S. Court of Appeals for the Second Circuit, responding to a motion to dismiss, held that at least some of the plaintiffs had standing, finding that both the existing and future harms were sufficient to establish injury-in-fact. The court began its standing analysis by explaining that "[t]he procedural posture of a case is important when assessing standing", and that when considering a motion to dismiss, courts should "presume that general factual allegations embrace those facts necessary to support the claim."[383] The court further noted that defendants "may certainly test [plaintiffs'] standing as the litigation progresses by requesting an evidentiary hearing or by challenging [plaintiffs'] standing on summary judgment or even at trial" but that the "allegation of a credible risk" is sufficient at the pleading stage, as "[a]dopting a more stringent view of [standing requirements] would essentially collapse the standing inquiry into the merits."[384]

With regards to existing injuries, the court found that that California's alleged injuries from sea level rise and snowpack melt "far exceed the 'identifiable trifle' required by Article III."[385] With regards to whether the future harms were sufficiently imminent, the court cited precedent holding that, in cases involving exposure to a harmful substance, it is the exposure that must be imminent and not the onset of disease.[386] The court then explained that the plaintiffs' future injury claims in the present case were even "more compelling" because, according to plaintiffs, the "defendants are currently emitting large amounts of carbon dioxide and will continue to do so in the future" and the adverse impacts to the plaintiffs were "certain to occur because of the consequences, based on the laws of physics and chemistry, of the documented increase in carbon dioxide in the atmosphere."[387] Thus, the

382. *Am. Elec. Power Co.*, 582 F.3d 309, 318 (2d Cir. 2009), *rev'd*, 564 U.S. 410 (2011).
383. *Id.* at 333.
384. *Id.* (internal citations omitted).
385. *Id.* at 342.
386. *Id.* at 344.
387. *Id.*

"future injuries they predict are anything but speculation and conjecture."[388]

Turning to the questions of causation and redressability, the court briefly noted plaintiffs' allegations that the defendants were the "five largest emitters of carbon dioxide in the United States" and that their emissions accounted for 2.5% of global emissions, but did not examine whether this constituted a "meaningful contribution" to global climate change.[389] The court explained that the fact that the defendants "contribute to" climate change was sufficient to allege causation in the context of a motion to dismiss, and that the significance of the contribution was "an issue best left to the rigors of evidentiary proof at a future stage of the proceeding, rather than dispensed with as a threshold question of constitutional standing."[390] In other words, the court determined that this issue should be addressed as part of its evaluation of the factual merits of the nuisance claim.[391] The court concluded that, "[f]or purposes of Article III standing, [the Plaintiffs] are not required to pinpoint which specific harms of the many injuries they assert are caused by particular Defendants, nor are they required to show that Defendants' emissions alone cause their injuries. It is sufficient that they allege that Defendants' emissions contribute to their injuries."[392] Citing *Massachusetts*, the court also held that the possibility of partial redress in this context was sufficient for standing purposes.[393]

On appeal, the Supreme Court announced that the eight justices hearing the case were equally divided on the standing issue and thus affirmed the Second Circuit's decision.[394] Four justices would have granted standing cited *Massachusetts* and did not perform any additional analysis, indicating that they viewed that case as controlling even where a procedural injury was not at stake.[395] Ultimately, the Court unanimously held that the case was non-justiciable because the federal common law claims had been

388. *Id.*
389. *Id.* at 345–47.
390. *Id.* at 347.
391. For more information about how the causation requirement differs in the standing and nuisance context, *see* Section III(C)(5).
392. *Am. Elec. Power Co.*, 582 F.3d at 347.
393. *Id.* at 348.
394. *Id.*
395. *Id.*

displaced by the Clean Air Act's grant of authority to EPA to regulate greenhouse gas emissions.[396] The Court did not address the state law claims.

iii. *Kivalina v. Exxon Mobil*

In *Native Village of Kivalina v. Exxon Mobil* (*Kivalina*), a Native Alaskan village sued approximately two dozen fossil fuel and energy generation companies for their contribution to climate change and the corresponding damages to the village (specifically, the cost of relocation), alleging a public nuisance under federal common law.

The district court reviewing this case had a very different perspective on standing than the Second Circuit in *American Electric Power*. It found that Kivalina lacked standing because it had not demonstrated that its injuries were "fairly traceable" to the defendants' actions because there were many other actors responsible for the emissions leading to damages in the village.[397] The court reached this conclusion even though the emissions at issue were significantly larger than those at issue in *American Electric Power*—specifically, Kivalina alleged that the defendant companies were jointly responsible for more than 1.2 billion tons of direct greenhouse gas emissions annually, as well as an unspecified quantity of indirect (downstream) greenhouse gas emissions generated by the combustion of fossil fuels extracted and sold by these companies.[398] As Kivalina put it, the defendants were responsible for a "substantial portion" of global greenhouse gas emissions.[399] Kivalina's complaint also included a detailed description of how greenhouse gas emissions were contributing to global climate change and, in turn, to localized impacts on Kivalina, such as melting permafrost and rising sea levels, which would force the village to relocate in the near future.[400]

The district court found that Kivalina had not alleged facts sufficient to be granted standing. On the question of whether a "contribution" to a problem may be sufficient to establish standing, it held that a contribution was not in-and-of-itself sufficient

396. *Id.* at 429.

397. Native Vill. of Kivalina v. Exxon Mobil Corp., 663 F. Supp. 2d 863, 880–81 (N.D. Cal. 2009), *aff'd on other grounds*, 696 F.3d 849 (9th Cir. 2012).

398. Complaint for Damages and Demand for Jury Trial ¶¶ 18–122, Native Vill. of Kivalina v. Exxon Mobil Corp., 663 F. Supp. 2d 863 (N.D. Cal. 2009) (No. CV 08 1138).

399. *Id.* ¶ 3.

400. *Id.* ¶¶ 123–62, 181–184.

evidence of harm and that plaintiffs had failed to show a "substantial likelihood" that the conduct of any one of the defendants actually harmed the village.[401] The court explained that:

> In view of the Plaintiffs' allegations as to the undifferentiated nature of greenhouse gas emissions from all global sources and their worldwide accumulation over long periods of time, the pleadings makes clear that there is no realistic possibility of tracing any particular alleged effect of global warming to any particular emissions by any specific person, entity, group at any particular point in time. Plaintiffs essentially concede that the genesis of global warming is attributable to numerous entities which individually and cumulatively over the span of centuries created the effects they now are experiencing. Even accepting the allegations of the Complaint as true and construing them in the light most favorable to Plaintiffs, it is not plausible to state which emissions—emitted by whom and at what time in the last several centuries and at what place in the world—"caused" Plaintiffs' alleged global warming related injuries. Thus, Plaintiffs have not and cannot show that Defendants' conduct is the "seed of [their] injury." To the contrary, there are, in fact, a multitude of "alternative culprit[s]" allegedly responsible for the various chain of events allegedly leading to the erosion of Kivalina.[402]

The district court did not specifically address whether there was some threshold at which standing could be established to sue emitters based on damages caused by climate change, but the court's analysis suggests that it would have reached the same decision regardless of the magnitude of the emissions.

On appeal, the Ninth Circuit followed the Supreme Court's decision in *American Electric Power* and dismissed the case due to legislative displacement, rather than a lack of standing.[403]

401. *Kivalina*, 663 F. Supp. 2d 863 at 880, *aff'd on other grounds* 696 F.3d 849 (9th Cir. 2012).

402. *Id.* at 880–81.

403. Native Vill. of Kivalina, 696 F.3d at 869. Justice Pro, in a concurring opinion, stated that he would have dismissed the case for lack of standing: "It is one thing to hold that a State has standing to pursue a statutory procedural right granted to it by Congress in the CAA to challenge the EPA's failure to regulate greenhouse gas emissions which incrementally may contribute to future global warming. *See* Mass. v. EPA, 549 U.S. 497, 516–20 (2007). It is quite another to hold that a private party has standing to pick and choose amongst all the greenhouse gas emitters throughout history to hold liable for millions of dollars in damages."

iv. *Washington Environmental Council v. Bellon*

The U.S. Court of Appeals for the Ninth Circuit grappled more directly with the question of what constitutes a sufficient contribution to climate change as part of the standing causation analysis in *Washington Environmental Council v. Bellon.* There, the court, responding to an appeal of a motion for summary judgment, held that two non-profits did not have standing to challenge Washington State's failure to regulate greenhouse gas emissions from five oil refineries, because they had not shown that the refineries' emissions made a meaningful contribution to global greenhouse gas levels.[404] The non-profits alleged that their members would experience adverse health impacts and property damage as a result of climate change, as well as aesthetic and recreational injuries because changes in precipitation patterns, reductions of glaciers, changes in wildlife habitat, and forest fires would affect natural areas that they routinely visit.[405] The court held that these injuries were sufficient to satisfy the injury-in-fact prong of the standing analysis but that the plaintiff had failed to establish causation.

Specifically, the court found that the plaintiffs' causation argument "consist[ed] of a series of links strung together by conclusory, generalized statements of 'contribution,' without any plausible scientific or other evidentiary basis that the refineries' emissions are the source of their injuries."[406] The court explained that:

> Greenhouse gases, once emitted from a specific source, quickly mix and disperse in the global atmosphere and have a long atmospheric lifetime. Current research on how greenhouse gases influence global climate change has focused on the cumulative environmental effects from aggregate regional or global sources. But there is limited scientific capability in assessing, detecting, or measuring the relationship between a certain GHG emission source and localized climate impacts in a given region.[407]

404. Wash. Envtl. Council v. Bellon, 732 F.3d 1131, 1135 (9th Cir. 2013), *reh'g en banc denied*, 741 F.3d 1075 (9th Cir. 2014).
405. *Id.* at 1140–41.
406. *Id.* at 1142.
407. *Id.* at 1143.

With regards to the defendants, the court noted that the refineries were responsible for 101.1 million metric tons of CO_2 annually (5.9% of total greenhouse gas emissions produced in the state of Washington), and that unlike the much larger quantity of emissions at issue in *Massachusetts v. EPA* (1.7 billion tons), the effect of those emissions on global climate change was "scientifically indiscernible, given the emission levels, the dispersal of GHGs world-wide, and the absence of any meaningful nexus between Washington refinery emissions and global GHG concentrations now or as projected in the future."[408] Thus, the court concluded that the causal chain was "too tenuous to support standing."[409]

The *Bellon* decision and other cases discussed above raise two important questions. First, at what threshold do emissions from a source represent a "meaningful contribution" to global climate change such that an adequate causal nexus can be found between those emissions and localized climate impacts? Or, in the words of the *Bellon* court, at what point is the effect of the emissions on global climate change sufficiently "scientifically discernible"? Detection and attribution research can help to answer this question, but there are also legal and policy judgments embedded in any determination of what constitutes a "meaningful" or "significant" contribution. Second, should this inquiry be conducted as part of the standing analysis, or is the question so closely tied to the merits that the issue should, in all or some subset of cases, be deferred to that later stage of the litigation? We return to this question in Section IV.

v. *Comer v. Murphy Oil*

The U.S. Court of Appeals for the Fifth Circuit also grappled with the question of standing for non-governmental entities to sue fossil fuel companies in *Comer v. Murphy Oil USA*. There, residents and

408. *Id.* at 1145. The court noted that the *Bellon* case also differed from *Massachusetts* because no procedural right was implicated and there was no state plaintiff that should be granted "special solicitude" in the standing analysis, but found that even if it "assume[d] that the Plaintiffs' members are entitled to a comparable relaxed standard, the extension of *Massachusetts* to the present circumstances would not be tenable."

409. *Id.* at 1144. *See also* Barnes v. U.S. Dep't of Transp., 655 F.3d 1124 (9th Cir. 2011) (finding that it was not possible to establish a link between greenhouse gas emissions from an increase in aviation activities caused by airport expansion and specific harmful impacts of climate change).

owners of lands and property along the Mississippi Gulf coast filed a class action lawsuit against energy, fossil fuel, and chemical companies alleging that the greenhouse gas emissions generated by these companies contributed to global warming, which in turn caused a rise in sea levels which exacerbated the effects of Hurricane Katrina.[410] The plaintiffs asserted claims for damages based on state common law actions of public and private nuisance, trespass, negligence, unjust enrichment, fraudulent misrepresentation, and civil conspiracy.[411] Unlike in *American Electric Power*, the plaintiffs did not pursue any federal common law action nor did they seek injunctive relief.[412] As in other cases, the defendants argued that the plaintiffs had not established an adequate causal connection between defendants' conduct and plaintiffs' harm.

The district court in Mississippi initially held that plaintiffs lacked standing,[413] but the Fifth Circuit reversed, holding that the landowners had Article III standing to bring their nuisance, trespass, and negligence claims.[414] The court noted that fully addressing the defendants' causation arguments would require the court to address the merits of plaintiffs' claims and was therefore "misplaced at this thresholds standing stage of the litigation."[415] It further explained that "the Article III traceability requirement need not be as close as the proximate causation needed to succeed on the merits of a tort claim" and that "an indirect causal relationship will suffice" for the purposes of Article III standing.[416] The Fifth Circuit thus took a very different approach from the Ninth Circuit in *Bellon*, noting that it must take the plaintiff's allegations that the defendants' emissions caused their injuries as true at the pleading stage, recognizing that the plaintiffs would be required to support those assertions at a later stage in the litigation.[417]

410. Comer v. Murphy Oil USA, 585 F.3d 855, 859 (5th Cir. 2009).
411. *Id.* at 859–60.
412. *Id.* at 860.
413. Comer v. Murphy Oil USA, Inc., No. 1:05-CV-436-LG-RHW, 2007 WL 6942285, at *1 (S.D. Miss. Aug. 30, 2007), *rev'd sub nom* Comer v. Murphy Oil USA, 585 F.3d 855 (5th Cir. 2009).
414. Comer v. Murphy Oil USA, 585 F.3d at 879–80.
415. *Id.* at 864.
416. *Id.*
417. *Id.*

The decision did not stand for long: the Fifth Circuit granted a rehearing en banc shortly after issuing the decision, and subsequently lost its quorum to decide the case before hearing it. The court ultimately held that it must dismiss the appeal due to lack of quorum and thus, the vacatur of the original panel decision remained in place.[418]

vi. *Juliana v. United States*

More recently, in *Juliana v. United States,* a federal district court in Oregon held that plaintiffs suing the U.S. government for affirmatively contributing to climate change and failing to control emissions from fossil fuel development and use had adequately alleged that they had standing to sue.[419] The court, responding to a motion for dismiss, noted that "general factual allegations" were sufficient to establish Article III standing.[420] The court found that the plaintiffs had established sufficiently personalized and concrete injuries—such as lost income for a ski resort employee, and harmful impacts to a family farm—that were fairly traceable to the greenhouse gas emissions resulting from U.S. fossil fuel production and use.[421] The court distinguished the case from *Bellon* on two grounds:

> (1) The procedural posture of the case was different: *Bellon* involved a motion for summary judgment, which is typically filed after the parties have completed discovery, whereas the *Juliana* court was responding to a motion to dismiss, which is filed shortly after the complaint is filed and which can only be granted where there is no genuine issue of material fact.[422]
>
> (2) The emissions at issue in *Juliana* (from all U.S. fossil fuels) were significantly larger than the emissions at issue in *Bellon* (from five refineries), and by no means represented a "minor contribution" to climate change.[423]

418. Comer v. Murphy Oil USA, 607 F.3d 1049, 1055 (5th Cir. 2010).
419. Juliana v. United States, 217 F. Supp. 3d 1224, 1248 (D. Or. 2016).
420. *Id.* at 1268.
421. *Id.* at 1267–68.
422. *Id.* at 1245.
423. *Id.*

The court also rejected the idea put forth by the district court in *Kivalina*—that causation between emissions and impacts cannot be established where there are "a multitude of alternative culprits" that are also responsible for climate change—and found that "a causal chain does not fail simply because it has several links, provided those links are not hypothetical or tenuous and remain plausible."[424] It summarized the causal chain as follows:

> DOT and EPA have jurisdiction over sectors producing sixty-four percent of United States emissions, which in turn constitute roughly fourteen percent of emissions worldwide; they allow high emissions levels by failing to set demanding standards; high emissions levels cause climate change; and climate change causes plaintiffs' injuries.[425]

Finally, with regards to redressability, the court noted that the requested remedy—ordering the U.S. government to "prepare and implement an enforceable national remedial plan to phase out fossil fuel emissions"—would "slow or reduce" the harm caused to plaintiffs, and that was sufficient for standing.[426]

The court subsequently denied a motion for summary judgement, again declining to find that plaintiffs lacked standing to sue, and citing many of the considerations noted above. The court acknowledged that a different standard applies when reviewing a motion for summary judgment (which is typically filed after the parties have completed discovery) as compared with a motion to dismiss.[427] At this stage, plaintiffs must establish that there is a "genuine question of material fact as to the standing elements."[428] The court found that the affidavits and expert testimony submitted by plaintiffs during discovery met this requirement, and noted that it would revisit all elements of standing after the factual record had been fully developed at trial.[429]

The district court's summary judgment decision was reversed by the Ninth Circuit in early 2020 based on the appellate court's

424. *Id.* at 1268.
425. *Id.* at 1246.
426. *Id.* at 1247.
427. Juliana v. United States, 339 F. Supp. 3d 1062, 1086 (D. Or. 2018), *mandamus dismissed sub nom.* In re United. States, No. 18-505, 2019 WL 3462578 (U.S. July 29, 2019).
428. *Id.* at 1086–87.
429. *Id.* at 1096. *See infra* section III(C)(5) for a more detailed discussion of the expert testimony submitted during discovery.

determination that plaintiffs had not satisfied the redressability prong of Article III standing.[430] Specifically, the court concluded that it could not provide the redress plaintiffs were seeking—an order requiring the government to develop a plan to phase out fossil fuel emissions and reduce atmospheric CO_2—because providing such relief would implicate policy choices reserved for the elected branches of government and thus violate the separation of powers doctrine.[431] Importantly, the Court of Appeals did find that the plaintiffs had satisfied the injury and causation requirements of Article III standing, for the purposes of summary judgment, because the plaintiffs had claimed concrete and particularized injuries and there was a genuine factual dispute as to whether federal policies were a "substantial factor" in causing the plaintiffs' injury.[432] In reaching this conclusion, the court cited the U.S.'s historical and current contribution to global emissions and evidence submitted by plaintiffs that federal subsidies and leases had increased those emissions.[433] It also rejected the government's reliance on *Bellon* to argue that the causal chain is too attenuated for standing purposes, noting that the plaintiff's alleged injuries arose from "a host of federal policies, from subsidies to drilling permits, spanning over 50 years" (whereas *Bellon* involved a failure to regulate five oil refineries).[434] Thus, the Court of Appeals' decision was not based on any deficiencies in the underpinning science or causal chain linking government inaction to climate impacts.

vii. Foreign Jurisdictions

Some foreign courts have also grappled with the question of what constitutes a "meaningful contribution" to climate change for standing purposes. For example, in *Dual Gas Pty Ltd. v. Environment*

430. Juliana v. United States, No. 18-36082 (9th Cir. Jan. 17, 2020).

431. This is similar to the separation of powers arguments cited by some judges in dismissing lawsuits brought against fossil fuel companies. See Section III(C)(5) *infra*. In *Juliana*, the plaintiffs argued that the court need not itself make policy decisions in issuing an order to the government to take action, since the court defer to the elected branches of government to decide how to implement the order. The court disagreed, finding that the plaintiff's requested relief would require it to pass judgment on the *sufficiency* of the government's implementation of the order, which would necessarily entail a broad range of policymaking. *Juliana*, No. 18-36082 at *26.

432. *Juliana*, No 18-36082 at *19–21.

433. *Id.*

434. *Id.* at 20.

Protection Authority, the Victorian Civil and Administrative Tribunal in Australia made the following observations when determining whether plaintiffs had standing to sue the government's approval of a new power plant:

> [D]espite the global nature of the GHG issue, there must still be a materiality threshold in relation to the type or size of the works or emissions that is relevant to whether a person's interests are genuinely affected, as opposed to being too remote or too general. The emission of a few tonnes of GHG from a small factory in Gippsland would not in our view give rise to standing under s 33B(1) to an objector in Mildura even though it represents an incremental GHG increase. It is unnecessary for us to determine where the line of materiality might be drawn. As we noted in our introduction, the DGDP is a major power station that will generate up to 4.2 million tonnes of GHG per annum over a 30 year projected life cycle and increase Victoria's GHG emissions profile by 2.5% over 2009 levels. In our view, this clearly raises potential issues of material interest or concern to all Victorians, and creates an almost unique level of "affected interests" and standing compared to the more usual sort of works approval matters that come before the Tribunal.[435]

Of course, standing requirements in states and most, if not all, foreign jurisdictions are not as stringent as standing requirements in U.S. federal courts. In some decisions, there is no standing analysis.[436] In others, the standing analysis is of a more general nature and does not require plaintiffs to show that they incurred a particularized harm as a result of the greenhouse gas emissions that might be controlled as a result of judicial intervention, with the result that attribution science plays a less critical role in the standing analysis.[437] Because the standards are more permissive, standing has not been a significant obstacle to climate change cases outside of the United States, nor have attribution questions factored heavily in the standing analyses.[438]

435. *Dual Gas Pty Ltd. v Env't Protection Authority* [2012] VCAT 308, ¶ 134. (Austl.).

436. *See, e.g.*, Leghari v. Republic Fed'n of Pakistan (2015) W.P. No. 25501/2015. For more on standing to bring climate-related lawsuits in non-U.S. jurisdictions, see BURGER & GUNDLACH, *supra* note 10.

437. *See, e.g.*, Rb Den Haag 24 juni 20015, m.nt. C/09/00456689 HA ZA 3-1396 (Urgenda Stichting/Staat der Nederlanden) (Neth.) [hereinafter *Urgenda* District Court Decision (2015)].

438. *See* BURGER & GUNDLACH , *supra* note 10.

The inconsistencies within the case law on standing in the United States, and as between U.S. courts and foreign jurisdictions, reinforce the conceptual and practical difficulties that have bedeviled analysis of climate change litigation. In *Massachusetts*, 6% of global GHG emissions was found to be a "meaningful contribution" sufficient to show causation, and states were granted "special solicitude" in proving standing.[439] In *American Electric Power*, 2.5% of global GHG emissions was enough for the Second Circuit, and for at least four judges then sitting on the Supreme Court.[440] In *Kivalina*, a district court judge focused not on the quantity of emissions or the question of their significance, but the impossibility of tracing specific impacts to specific emissions.[441] In *Bellon*, the Ninth Circuit determined that 5.9% of Washington State's GHG emissions could not be effectively disaggregated from the global co-mingling of GHGs to establish causation.[442] In *Comer*, a Fifth Circuit panel found that allegations that a large number of companies had made a significant contribution were sufficient to survive a motion to dismiss. In *Juliana*, the district court noted that U.S. agencies had regulatory authority over at least 14% of global GHGs and found it sufficient.[443]

All of which leaves open a number of questions: What quantity of emissions matters? Which sources or actors are relevant for calculating contributions? What is the best, or at least an appropriate, means of aggregating the actors and their emissions for the purposes of calculating contributions? What is the state of the science in measuring the relationship between individual sources/actors and localized impacts? These questions matter for standing. As discussed further below, they matter on the merits, as well.

2. Evidentiary Standards for Scientific Testimony and Reports

A threshold consideration regarding the role of attribution science in the courtroom is whether expert testimony on attribution is admissible in court. The *Daubert* standard, first articulated by the Supreme Court in *Daubert v. Merrell Dow*

439. *See supra* Section III(C)(1)(b)(i).
440. *See supra* Section III(C)(1)(b)(iii).
441. *See supra* Section III(C)(1)(b)(iv).
442. *See supra* Section III(C)(1)(b)(v).
443. *See supra* Section III(C)(1)(b)(vi).

Pharmaceuticals,[444] is the contemporary standard for admissibility in federal courts and many states have adopted this standard as well. That standard charges the judge with ensuring that the basis of the expert's testimony is "scientific knowledge"[445] and outlines the following factors for making this determination:

- Whether the scientific theory or technique can be (and has been) tested
- Whether it has been subjected to peer review and publication
- Whether it has a known error rate
- Whether it has a degree of "general acceptable" within a "relevant scientific community."[446]

Most states now follow the *Daubert* standard, but some adhere to the less exacting *Frye v. United States* standard (the previous federal standard),[447] which only requires "general acceptance" of the science within the relevant scientific community.[448] These standards are typically only evoked when the opposing side challenges expert testimony.

Most attribution studies accord with the *Daubert* standard insofar as they rely on scientific theories that can be tested using models, statistical analyses, and observations; they are typically published in peer reviewed journals; they typically discuss known sources of bias and the potential for Type I and Type II errors; and they are based on generally accepted techniques. However, defendants in climate lawsuits may argue that some of the more novel impact and event attribution techniques do not meet all four requirements, and in particular, the requirement of "general acceptance" within the scientific community. Defendants are also highly likely to challenge testifying scientists who draw inferences from attribution studies with respect to impacts not explicitly covered in those studies, even where the underlying studies would clearly satisfy

444. Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1993).
445. *Id.* at 592.
446. *Id.* at 592–95.
447. 293 F. 1013 (D.C. Cir. 1923).
448. Michael Morgenstern, Daubert *v.* Frye*: A State-by-State Comparison*, THE EXPERT INST. (Apr. 3, 2017), https://www.theexpertinstitute.com/daubert-v-frye-a-state-by-state-comparison/ [https://perma.cc/5UF2-F5JQ].

Daubert.[449] This highlights the benefits of using attribution studies of an appropriate scale and scope.

One important question is whether and to what extent confidence levels will affect the admissibility of and weight given to attribution studies presented to courts. As noted in Part II, attribution findings are frequently presented in terms of confidence levels and intervals—for example, a study may find with ">90% confidence" that anthropogenic forcing on climate doubled the risk of an extreme event occurring. The National Academy of Sciences ("NAS") *Reference Manual on Scientific Evidence* notes that a 95% confidence level is the "standard" for scientific studies but does not recommend a threshold for admissibility in court, nor does it discuss how confidence levels might affect the weight afforded to a scientific study.[450] Apart from that manual, there does not appear to be any clear standard for dealing with confidence levels and intervals in courtrooms. Many, but not all, attribution studies present findings at the 95% confidence level, consistent with general scientific practice. This bodes well for the utilization of the research in courts, but there may be situations where it is also useful to discuss findings at lower confidence levels (the goal being to identify what is plausible, even if not highly certain). Part IV presents recommendations on how researchers might frame their research to satisfy the demands of the courtroom as well as other applications.

There is no single numeric standard that juries and courts rely on in assessing the weight of scientific expert testimony.[451] Generally speaking, judges and juries will consider factors such as believability, persuasiveness, thoroughness, and whether the evidence has been refuted.[452] Evidence that is indefinite, vague, or improbable will generally be given less weight than evidence that is

449. For more on this topic, *see* Kirsten Engel & Jonathan Overpeck, *Adaptation and the Courtroom: Judging Climate Science*, 3 MICH. J. ENVTL. & ADMIN. L. 1 (2013).

450. FED. JUD. CTR., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE: THIRD EDITION 284–85 (National Academies Press 2011) https://www.fjc.gov/sites/default/files/2015/SciMan3D01.pdf [https://perma.cc/3SEB-JN9L].

451. Note the burden of proof in civil trials is the "preponderance of evidence" standard, which requires a plaintiff to convince the trier of fact that the evidence in support of her case outweighs the evidence offered by the defendant to oppose it.

452. *Weight of the Evidence*, WEST'S ENCYCLOPEDIA OF AMERICAN LAW (2d ed. 2008), https://legal-dictionary.thefreedictionary.com/weight+of+evidence [https://perma.cc/44VB-TD4W].

direct and unrefuted.[453] The weight afforded to attribution findings will thus depend on the level of uncertainty underpinning those findings as well as the extent to which the findings are a subject of scientific debate.

3. Lawsuits Challenging the Failure to Regulate Greenhouse Gas Emissions

Environmental and citizen groups in the United States and other jurisdictions have brought numerous challenges seeking to compel governments to take action to curtail greenhouse gas emissions.[454] There are three types of lawsuits that fall within this category: (i) lawsuits challenging the government failure to implement statutory mandates with respect to air pollution control; (ii) lawsuits challenging the failure to protect public health pursuant to general legal mandates recognized in constitutions, public trust doctrines, human rights law, and other legal sources; and (iii) lawsuits involving administrative decisions undertaken within an existing regulatory scheme, typically decisions to grant or refuse an authorization for a particular activity (such as coal mining or the construction of an airport). In all three types of cases, attribution science comes into play when plaintiffs need to establish a causal connection between the government's action or inaction and concrete harms caused by climate change to succeed on the merits.

a. Lawsuits Challenging the Failure to Implement Statutory Mandates With Respect to Air Pollution Control

i. *Massachusetts v. EPA*

The most noteworthy case involving a government failure to regulate greenhouse gas emissions pursuant to an existing statutory scheme for air pollution control was *Massachusetts*. In the same way that attribution science helped plaintiffs establish standing in this

453. *Id.*

454. Cases involving a common law breach of a government duty owned to plaintiffs are sometimes referred to as "public liability" cases in contrast to the "private liability" cases discussed in subsequent sections. *See* Jutta Brunnée et al, *Overview of Legal Issues Relevant to Climate Change*, in CLIMATE CHANGE LIABILITY: TRANSNATIONAL LAW AND PRACTICE 23 (Richard Lord et al. eds., Cambridge University Press 2012).

case, it also helped them to rebut EPA's assertion that it there was too much scientific uncertainty about climate change to regulate.[455]

The case history is illuminating. The D.C. Circuit initially dismissed the case but did not reach consensus on the basis for dismissal, in part due to disagreements about the scientific underpinnings of EPA's views about scientific uncertainty. In Judge Randel's plurality opinion, he wrote that EPA had properly declined to regulate based on its conclusions that there was too much scientific uncertainty about the causal effects of greenhouse gases on climate change.[456] In reaching this conclusion, the judge referred to EPA's reliance on a 2001 National Research Council ("NRC") report, which found that "a causal linkage" between greenhouse gas emissions and global warming "cannot be unequivocally established."[457] He summarized the NRC's findings as follows:

> The earth regularly experiences climate cycles of global cooling, such as an ice age, followed by periods of global warming. Global temperatures have risen since the industrial revolution, as have atmospheric levels of carbon dioxide. But an increase in carbon dioxide levels is not always accompanied by a corresponding rise in global temperatures. For example, although carbon dioxide levels increased steadily during the twentieth century, global temperatures decreased between 1946 and 1975. Considering this and other data, the National Research Council concluded that "there is considerable uncertainty in current understanding of how the climate system varies naturally and reacts to emissions of greenhouse gases." This uncertainty is compounded by the possibility for error inherent in the assumptions necessary to predict future climate change. And, as the National Research Council noted, past assumptions about effects of future greenhouse gas emissions have proven to be erroneously

455. Uncertainty was only one of the rationales proffered by EPA for not regulating motor vehicle emissions. EPA also argued that: (i) it did not have statutory authority to regulate greenhouse gas emissions, and (ii) even if did have authority to regulate, there were "policy considerations" which made it unwise for EPA to exercise that authority at this time. *Massachusetts*, 549 U.S. at 513–514. *See also* citing EPA, Control of Emissions from New Highway Vehicles and Engines: Notice of Denial of Petition for Rulemaking, 68 Fed. Reg. 52922, 52929–31 (Sept. 8, 2003).

456. *Massachusetts*, 415 F.3d at 58. (The court also supported EPA's determination that policy considerations weighed against regulating greenhouse gases at this time.)

457. *Id.* at 57 (citing NAT'L RES. COUNCIL, CLIMATE CHANGE SCIENCE: AN ANALYSIS OF SOME OF THE KEY QUESTIONS (2001)).

high.[458]

In light of this perceived uncertainty, Judge Randel concluded that it was neither arbitrary nor capricious for EPA to decline to regulate greenhouse gas emissions at the time.[459] Judge Sentelle, concurring in the decision to dismiss the case, asserted that the court lacked jurisdiction to hear the case on standing grounds.[460] Judge Tatel dissented, arguing that the NRC report actually did provide a sufficient basis for a finding that greenhouse gas emissions endangered public health and welfare and should therefore be regulated under the Clean Air Act.[461] Notably, the dissenting judge provided a more detailed synthesis of the NRC report's findings, which contradicted Judge Randel's interpretation of the report. Some of the key points highlighted were that:

> The very first sentence of the NRC report stated that "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise." The quote used by Judge Randel (that "a causal linkage" between greenhouse gas emissions and global warming "cannot be unequivocally established") had been taken out of context, and was merely a recognition that this linkage, as with many other scientific theories, could not be established with 100% certainty.[462]
> The NRC report made clear that uncertainties about climate change related chiefly to the scope and magnitude of impacts caused by greenhouse gas accumulation, not whether there was a correlation between those emissions and global warming.[463]
> The NRC report explicitly acknowledged that "national policy decisions made now and in the longer-term future will influence the extent of any damage suffered by vulnerable human populations and ecosystems later in this century."[464]

On review, the Supreme Court acknowledged that uncertainty *might* be a reasonable basis for not regulating, but held that EPA cannot defer regulation unless it issued a formal declaration that

458. *Id.* (internal citations omitted).
459. *Id.* at 58.
460. *Id.* at 60–61 (Sentelle, J., concurring).
461. *Id.*at 61–82 (Tatel, J., dissenting).
462. *Id.* at 63.
463. *Id.* at 64.
464. *Id.* at 64.

the uncertainty was "so profound that it preclude[d] EPA from making a reasoned judgment as to whether greenhouse gases contribute to global warming."[465] While the Court did not decide the issue, it did clearly indicate that it might not uphold a determination of uncertainty from EPA—it noted the "harms associated with climate change are serious and well-recognized" and that the "Government's own objective assessment of the relevant science and a strong consensus among qualified experts indicate that global warming threatens, *inter alia,* a precipitate rise in sea levels, severe and irreversible changes to natural ecosystems, a significant reduction in winter snowpack with direct and important economic consequences, and increases in the spread of disease and the ferocity of weather events."[466]

ii. *Coalition for Responsible Regulation v. EPA*

Following the Supreme Court's decision in *Massachusetts*, EPA issued an endangerment finding for GHG emissions from motor vehicles, finding that such emissions cause or contribute to the endangerment of public health and welfare. The D.C. Circuit upheld this determination in *Coalition for Responsible Regulation v. EPA*.[467] There, an industry group argued that there was "too much uncertainty" about the science underpinning climate change and that EPA had improperly relied on external studies from the IPCC, U.S. Global Change Research Program, and U.S. National Research Council in reaching its decision.[468] The court rejected these claims and held that EPA's reliance on external studies was entirely proper—noting that "EPA is not required to re-prove the existence of the atom every time it approaches a scientific question"—and held that the scientific body of evidence underpinning the endangerment finding was "substantial" and therefore legally sound.[469] In reaching this conclusion, the court explained that EPA had addressed each link in the causal chain connecting

465. *Massachusetts*, 549 U.S. at 534.

466. *Id.* at 499.

467. Coal. for Responsible Regulation, Inc. v. EPA., 684 F.3d 102, 121 (D.C. Cir. 2012), *aff'd in part, rev'd in part sub nom* Util. Air Regulatory Grp. v. EPA., 573 U.S. 302 (2014), and *amended sub nom* Coal. for Responsible Regulation, Inc. v. EPA, 606 F. App'x 6 (D.C. Cir. 2015). *See also* Biogenic CO2 Coal. v. EPA, No. 16-1358 (D.C. Cir. filed Oct. 14, 2016) (challenging endangerment finding for GHG emissions from aircraft).

468. *Coal. for Responsible Regulation, Inc.*, 684 F.3d at 121.

469. *Id.* at 120.

anthropogenic greenhouse gas emissions to harmful impacts on public health and welfare and that EPA had provided three lines of evidence to support the finding: (i) our "basic physical understanding" of the greenhouse gas effect, (ii) observational evidence of past climate change, and (iii) models predicting how the climate will response to greenhouse gas concentrations in the future.[470]

iii. Other Clean Air Act Cases

Above, we describe how attribution science has played a central role in the issuance and judicial review of Clean Air Act endangerment findings. This would also be the case if EPA exercised its authority to establish National Ambient Air Quality Standards ("NAAQS") for GHGs under Section 110 or if EPA developed a program to control GHG emissions as a source of international air pollution under Section 115 of the Act.[471] To establish NAAQS for GHGs, EPA would need to identify thresholds for ambient concentrations of GHGs that are sufficient to protect public health and welfare. Similarly, to establish a Section 115 program, EPA would need to establish targets for emission reductions as necessary to "prevent or eliminate the endangerment" that those emissions pose to foreign nations. In either case, it would be necessary to define the appropriate threshold for emission control based on, among other things, both existing impacts as well as predictions of future impacts of climate change.

The Clean Air Act and other air pollution control statutes also provide for the establishment of technology-based emission standards (e.g., standards reflecting the "best available technology" or the "best system of emission reduction.").[472] In this context, attribution science plays a less pivotal role in the establishment and judicial review of the standards, since the standards are primarily based on considerations pertaining to statutory authority, technological feasibility, and cost. However, challenges to and

470. *Id.* at 120–21.

471. See Michael Burger et al., *Legal Pathways to Reducing Greenhouse Gas Emissions under Section 115 of the Clean Air Act*, 28 GEO. ENVTL. L. REV. 359 (2016); Kassie Siegel et al., *Strong Law, Timid Implementation. How the EPA Can Apply The Full Force of the Clean Air Act To Address The Climate Crisis*, 30 UCLA J. ENVTL. L. & POL'Y 185 (2012).

472. *See, e.g.*, Clean Air Act § 111(a)(1), 42 U.S.C. § 7411 (2018).

defenses of these standards do involve attribution questions to some extent—for example, when defining the "best system of emission reduction" for controlling emissions from stationary sources under the Clean Air Act, EPA must take into account the public health benefits of the standards as well as technological feasibility and cost.[473] But to date, attribution science has not featured prominently in litigation over technology-based and hybrid rules and standards such as the Clean Power Plan.[474]

b. Cases Challenging the Government Failure to Protect Public Health Pursuant to Constitutional Mandates, Public Trust Doctrines, Human Rights Law, and Other Legal Sources

A number of cases have been brought challenging the failure to regulate greenhouse gas emissions and fossil fuel production on the grounds that government entities have violated more general mandates pertaining to fundamental rights. In the United States, there are at least two federal legal sources that have given or could give rise to such cases: the public trust doctrine, which holds that government actors have a duty to preserve certain "public trust" resources for future generations;[475] and the theory of substantive due process, which holds that the federal government must safeguard fundamental rights that are "implicit in the concept of ordered liberty" or "deeply rooted in this Nation's history and tradition."[476] States and other jurisdictions also have a variety of different common law, constitutional, and statutory requirements that oblige government actors to protect public welfare, human rights, or the environment, which can support such claims.[477] In these cases, attribution science is primarily used to demonstrate a causal connection between the under-regulated greenhouse gas emissions and specific injuries to public health and welfare or the

473. *Id.*

474. *See, e.g.*, West Virginia v. EPA, No. 15-1363 (D.C. Cir. 2015); North Dakota v. EPA, No. 15-1381 (D.C. Cir. 2015).

475. Ill. Ctr. R.R. Co. v. Illinois, 146 U.S. 387 (1892).

476. McDonald v. City of Chi., Ill., 561 U.S. 742, 761, 767 (2010).

477. For example, there have been a number of lawsuits filed under state constitutions and public trust doctrines due to state inaction on climate change, as well as foreign lawsuits filed pursuant to national constitutional obligations and human rights laws. *See, e.g.*, Funk v. Pennsylvania, 71 A.3d 1097 (Pa. Commw. Ct. 2013); Urgenda District Court Decision (2015); Leghari v. Pakistan (2015) WP No. 25501/201 (Lahore Hight Court) (Pak.). *See also Public Trust Doctrine*, SABIN CTR. FOR CLIMATE CHANGE L., http://climatecasechart.com/principle-law/public-trust-doctrine/ (last visited Jan. 6, 2020) [https://perma.cc/DH4B-N93K].

environment, which, in turn, give rise to the alleged breach of government duty.[478]

i. *Juliana v. United States*

In *Juliana*, the plaintiffs asserted that: (i) the U.S. government had violated "the fundamental right of citizens to be free from government actions that harm life, liberty, and property" by "approving and promoting fossil fuel development, including exploration, extraction, production, transportation, importation, exportation, and combustion" that had resulted in the degree of climate change we are now experiencing and are projected to experience in the future;[479] and (ii) the U.S. government also violated its public trust obligation to its citizens through this conduct.[480] To prove these claims, the plaintiffs would have needed to establish a causal connection between the emissions that the U.S. government had approved and/or failed to control and the alleged violations of their rights and/or the public trust doctrine.

The plaintiffs in *Juliana* emphasized the magnitude of the emissions at issue, noting that: (i) territorial emissions from the U.S. account for approximately 25.5% of the world's cumulative CO_2 emissions, and this figure would likely be higher using a consumption- or extraction-based accounting approach; (ii) emissions from U.S. energy consumption were 5.4 billion metric tons of CO_2 in 2014; (iii) if the government had acted on expert recommendations on how to limit emissions issued by EPA in 1990 and the Congressional Office of Technology Assessment in 1991, then U.S. CO_2 emissions would have been reduced by 35% from 1987 levels; and (iv) instead, since 1991, the U.S. government had "knowingly allowed at least an additional 130,466 million metric tons of CO_2 emissions from fossil fuel combustion."[481] Plaintiffs

478. In some instances it may also be the case that attribution science plays a role in positing the efficacy or level of protection available under the alternative scenario sought by plaintiffs.

479. Juliana v. United States, 217 F. Supp. 3d 1224, 1248 (D. Or. 2016).

480. The contours of the public trust doctrine, as interpreted by the plaintiffs and court in this case, are similar to the duty of care at issue in Urgenda District Court Decision (2015).

481. First Amended Complaint for Declaratory and Injunctive Relief ¶¶ 151–63, Juliana v. United States, 217 F. Supp. 3d. 1224 (D. Or. 2016) (No. 615-cv-01517-TC). This estimate of the U.S. emissions contribution was based on total emissions from energy production within the U.S. since 1991.

also dedicated a substantial portion of their complaint to explaining precisely how climate change is affecting and will affect their lives, liberty, and property interests, to support both their standing and merits claims.[482] The overarching theme of the complaint was that the plaintiffs, all being young people, are "especially vulnerable" to the threats caused by climate change.[483] It detailed existing and projected impacts on each of the individual children, such as adverse impacts on a farm where one of the children works and intends to pursue a livelihood;[484] lost income for a family that works at a ski resort;[485] and asthma attacks from the increased frequency of forest fires in Oregon (a result of hotter and drier temperatures).[486]

In her decisions denying the U.S. government's motion to dismiss and motion for summary judgment, the district court judge in Oregon held that the plaintiffs' allegations raised colorable substantive claims under the U.S. Constitution and the public trust doctrine.[487] The judge found that the substantive due process claim was supported by plaintiff's allegations that "the government has caused pollution and climate change *on a catastrophic level*, and that if the government's actions continued unchecked, they will permanently and irreversibly damage plaintiff's property, their economic livelihood, their recreational opportunities, their health, and ultimately their (and their children's) ability to live long, healthy lives."[488] With this in mind, the judge stated: "I have no doubt that the right to a climate system capable of sustaining human life is fundamental to a free and ordered society" and therefore was a constitutionally protected right.[489] The judge also found that the plaintiff's allegations were sufficient to establish a breach of the public trust doctrine, which prohibits government actors from "depriving a future legislature of the natural resources necessary to provide for the well-being and survival of its

482. *Id.* ¶¶ 16–97.
483. *Id.* ¶ 10.
484. *Id.* ¶¶ 23–28.
485. *Id.* ¶ 38.
486. *Id.* ¶ 46.
487. Juliana v. United States, 217 F. Supp. 3d. 1224 (D. Or. 2016); Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018).
488. *Juliana*, 217 F. Supp. 3d at 1250.
489. *Id.*

citizens."[490] She noted that it was unnecessary to determine whether the atmosphere was itself a public trust resource that must be preserved for future generations, because the territorial sea owned by the federal government has already been declared a public trust resource, and plaintiffs had alleged adequate harms to that resource caused by ocean acidification and rising ocean temperatures.[491]

As discussed above, the district court's decision was overturned by the Ninth Circuit Court of Appeals in early 2020.[492] Finding that the plaintiffs had failed to establish the redressability prong of Article III standing, the Court of Appeals remanded to the district court with orders to dismiss. Nonetheless, the work the parties put into preparation for an anticipated trial—and the district court's decision on the motion for summary judgment—reveals a great deal about how detection and attribution science would likely factor into resolution of other cases involving regulatory failures.

In preparation for trial, the plaintiffs submitted more than 1,000 pages of expert reports detailing the fundamental science of climate change, observed and projected impacts, and the ways in which the United States and the fossil fuel industry have contributed to the problem.[493] In some cases, the experts linked observed impacts directly to the plaintiff's alleged injuries, but some of these linkages draw on qualitative inferences about how broader trends related to climate change have affected or may affect the plaintiffs. For example, with respect to a plaintiff who

490. *Id.* at 1253. *But see* Alec L. v. Jackson, 863 F. Supp. 2d 11 (D.D.C. 2012) (holding that the public trust doctrine is a matter of state, not federal, law) (citing PPL Montana, LLC v. Montana, 565 U.S. 576 (2012)).

491. *Juliana*, 217 F. Supp. 3d at 1256 (citing First Amended Complaint ¶ 16 ("An important part of Kelsey's diet includes food that comes from the marine waters and freshwater rivers, including salmon, cod, tuna, clams, mussels, and crab."); *id.* ¶ 27 ("Other food sources for Alex, including crab and seafood, are negatively impacted by ocean acidification, warming, and sea level rise caused by Defendants."); *id.* ¶ 33 ("Ocean acidification caused by Defendants has already begun to adversely impact shellfish along the coast, and is predicted to take its toll on crab, mussels, and all shelled seafood."); *id.* ¶ 45 ("On the Oregon coast, Sahara enjoys climbing rocks and sand dunes, swimming, and tidepooling to see marine life. Sahara's enjoyment of these activities is being increasingly harmed in the future by sea level rise, greater erosion, enhanced ocean acidification, and increased water temperatures.").

492. *See infra* Section III(C)(1).

493. *See U.S. Climate Change Litigation:* Juliana v. United States, SABIN CTR. FOR CLIMATE CHANGE L., http://climatecasechart.com/case/juliana-v-united-states/ [https://perma.cc/7DBD-37KP] (last visited Jan. 6, 2020).

had to move from her home in Cameron, Arizona because the springs her family depended on for water were drying up, one expert noted that the "pattern of drought in places like Arizona is directly linked to climate change" without citing research specifically attributing the arid conditions in the area to climate change.[494] Similarly, experts reporting on public health impacts noted that the youth plaintiffs, like all children, are at a higher risk of certain health problems such as asthma due to climate change but did not attribute specific health problems experienced by individual plaintiffs to climate change.[495] In other cases, statements about impacts on plaintiffs were based on observed trends and impacts without reference to attribution studies like those described in Section II.[496] Arguably more robust linkages were drawn between climate change and alleged injuries based on downscaled climate impact data—for example, data on historic and projected sea level rise in the town where one plaintiff lived,[497] and attribution studies linking specific extreme events that affected plaintiffs to anthropogenic climate change.[498]

Regarding the question of source attribution and the U.S. contribution to climate change, Dr. James Hansen prepared a lengthy expert report and an accompanying paper on *Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature*, which he co-authored with other scientists and economists.[499] Hansen cited research finding that the U.S. is an "unambiguous leader" in cumulative GHG emissions, having generated approximately 25% of emissions since 1751 ("more than double that of China, which

494. Expert Report of Steven W. Running, Ph.D at 6, Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517).

495. Expert Report of Susan E. Pacheco, M.D. and Jerome A. Paulson, M.D., FAAP, Juliana v. United States, 339 F. Supp. 3d 1062 (2018) (No. 6:15-cv-1517).

496. *See*, *e.g.*, Expert Report of Steven Running, *supra* note 494, at 9 ("Ski areas like Hoodoo Pass and Willamette Pass in Oregon, where Plaintiff Zealand recreates and his family has been employed, and Stevens Pass in Washington, where Plaintiff Aji recreates, have recently had years with so little snow the areas could not even open for business.")

497. Expert Report of Dr. Harold R. Wanless at 24, Juliana v. United States, 339 F. Supp. 3d 1062 (2018) (No. 6:15-cv-1517).

498. Expert Report of Dr. Kevin Trenberth at 18–22, Juliana v. United States, 339 F. Supp. 3d 1062 (2018) (No. 6:15-cv-1517).

499. Expert Report of James E. Hansen, Juliana v. United States, 339 F. Supp. 3d 1062 (2018) (No. 6:15-cv-1517).; *see also* James E. Hansen et al., *Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature*, 8 PLOS ONE 12 (Dec. 2013).

falls second in the ranking"), and that the United States alone is responsible for a 0.15°C increase in global temperature. Dr. Hansen discussed emission reduction targets for the U.S. based on a global climate budget.[500] Dr. Hansen also discussed impacts such as sea level rise but did not explicitly quantify the proportional contribution of the United States to those impacts.

The question of the United States' responsibility for climate change was further explored in an expert report from Peter Erickson, a scientist at the Stockholm Environment Institute. He noted that the U.S. produces a substantial quantity of "territorial" emissions but that this is an incomplete indicator of responsibility for climate change.[501] He called for consideration of the United States' consumption emissions, which are approximately 20% higher than territorial emissions in recent decades, as well as extraction-based emissions, since the country also bears some responsibility for emissions from the burning of fossil fuels produced in the United States.[502] His expert testimony contained a comparison of U.S. emissions under all three accounting approaches. Erickson also noted that the United States has contributed to climate change by leasing and subsidizing the production of fossil fuels, but did not quantify the effect of those leases and subsidies on climate change (vis-à-vis global mean temperature change) or its impacts. Notably, Erickson did not suggest that one accounting approach should dominate—but rather that all three approaches should be considered when assessing U.S. responsibility for climate change.

The U.S. government also solicited numerous expert reports primarily aimed at countering the idea that plaintiffs' injuries could be traced to U.S. government conduct. With respect to impact attribution, the defense experts argued that the plaintiffs' experts have failed to establish a conclusive link between anthropogenic climate change and the plaintiffs' alleged injuries because they infered that climate change caused the injuries based

500. Expert Report of James Hansen, *supra* note 499, at 26–27.

501. Expert Report of Peter A. Erickson at 3, Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517).

502. *Id.* ("To more fully reflect its contribution to global climate change, it is my opinion that the Federal Government should also regularly conduct both a consumption-based and an extraction-based GHG emissions inventory.").

on observations and general trends[503] without accounting for other confounding factors that may have been responsible for the injuries.[504] The defendants' experts also addressed the question of source attribution—that is, the question of U.S. government responsibility and ability to provide redress for climate change-related injuries. They argued that the plaintiffs' experts have failed to specify the degree to which U.S. government conduct is responsible for climate change or the plaintiffs' alleged injuries, [505] and failed to demonstrate that the U.S. government could provide adequate redress for the alleged injuries through policy and regulatory actions.[506] They also disputed the share of global

503. *See, e.g.*, Notice of Supplemental Disputed Facts Raised By Defendants' Expert Reports In Support Of Plaintiffs' Response In Opposition To Defendants' Motion For Summary Judgment, Juliana v. United States, 6:15-cv-01517, Dkt. 338 (Aug. 24, 2018) (plaintiffs' health impact experts "never directly link[ed] any of the [psychiatric and medical consequences of climate change] to any individual plaintiffs. They remain theoretical possibilities, reported in various studies of natural disasters, but *not* conclusively identified in any of the Plaintiffs she examined."), Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517); Expert Report of Dr. Norman I. Klein at 5 ("Drs. Frumkin, Pacheco, and Paulson confuse general correlations from abstract epidemiological studies with clinical examination of specific instances of asthma and allergy symptoms), Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517).

504. *See, e.g.*, Expert Report of Norman Klein, *supra* note 503, at 3 ("[e]ven if the individual Plaintiffs' complaints of allergy and asthma symptoms were credited, an exemption of other potential contributing factors must be evaluated before climate change could be determined as a contributing, much less primarily contributing, factor to these specific Plaintiffs."); Expert Report of Dr. John P. Weyant at 10 ("By failing to analyze the potential confounding effect of local conditions, Dr. Trenberth reaches conclusions about the impacts on Plaintiffs that are unsupported and therefore unreliable."), Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517); Expert Report of Dr. John P. Weyant at 15 ("When Prof. Running makes claims about injuries to Plaintiffs, he simply presumes that human-induced climate change is the major cause of the multiple hydrological and ecological changes that he discusses, despite the fact that population growth and migration, forest and water management practices, and wildfire and flood prevention measures are also important determinants of the climate events he analyzed."), Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517); Expert Report of Dr. John P. Weyant at 18 ("Complicated interactions are emblematic of the confounding factors that scientists need to consider when examining the influence of climate change. It is the part of the reason why Prof. Running's statement that an increased wildfire season due to climate change has and will affect many of the Plaintiffs is an overbroad assertion."), Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517).

505. *See, e.g.*, Expert Report of John Weyant *supra* note 504, at 11 ("Overall, Dr. Trenberth's conclusions are not supported by analysis that allows one to determine how and to what degree Jaime's experiences with water shortages, wildfires, droughts, or heat waves are exacerbated by human-induced climate change.").

506. *See, e.g.*, Expert Report of David G. Victor at 12 , Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517) ("US oil and gas producers extract

emissions attributable to U.S. government action or inaction.[507] One expert estimated that the U.S. government is responsible for no more than 4% of global emissions and that the other 96% of emissions are generated by: (i) countries other than the U.S., or (ii) fossil fuel consumption by entities other than the federal government that would have occurred regardless of federal policies and regulations.[508] Another expert estimated that, even under a consumption-based accounting approach, the share of emissions attributable to the U.S. government is only 5%.[509] Notably, both experts acknowledged that total U.S. emissions are much higher than these estimates regardless of whether a territorial-, consumption-, or extraction-based methodology is used, but they dispute the notion that the U.S. government is responsible for all U.S. emissions.[510] This was consistent with the approach taken by defendants in their answer to the original complaint, in which they admitted key facts about the proportion of global CO_2 emissions generated within the U.S. while maintaining that the U.S.

commodities worth $245b per year. The subsidy embodied in the output is only about 1.9% of the total market value of production. In my view, subsidies worth that tiny fraction of the total value are not material to an industry whose prices can swing many multiples of this percentage in a financial quarter."); Expert Report of David G. Victor at 19, Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517) ("The effect of oil subsidy reforms on emissions will be much smaller than suggested by Erickson, because other factors have a much larger impact on production decisions, the industry is highly competitive and responsive to changes in market conditions and production costs."); Expert Report of Dr. Daniel Sumner at 8 , Juliana v. United States, 339 F.Supp.3d 1062 (D. Or. 2018) (No. 6:15-cv-1517) ("I conclude that there is considerable doubt as to whether Dr. Robertson's proposed agricultural methods can deliver the amount of GHG abatement that Dr. Robertson claims at any price."). *See, e.g.*, Expert Report of David G. Victor at 4, Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) (No. 6:15-cv-1517) ("The effect of oil subsidy reforms on emissions will be small to zero.") ; Expert Report of Dr. James L. Sweeney at 13, Juliana v. United States, 339 F.Supp.3d 1062 (D. Or. 2018) (No. 6:15-cv-1517) ("If the U.S. halted its use and production of fossil fuels, the prices of these fuels would fall and other counties would increase their use of fossil fuels.").

507. *See, e.g.*, Expert Report of James Sweeney, *supra* note 506, at 66 ("Plaintiffs and their experts offer no analysis to link the failure to develop policies to the impacts on GHG emissions."); Expert Report of David G. Victor, *supra* note 506, at 5 ("Stiglitz fails to identify plausible, real-world actions that the U.S. government could have taken that would have led to appreciably different outcomes with respect to domestic and international energy systems."); Expert Report of James Sweeney, *supra* note 506, at 56 ("Only a very small fraction of these sources [of U.S. greenhouse gas emissions are] directly controlled by the federal government.").

508. Expert Report of James Sweeney, *supra* note 506, at 60.

509. Expert Report of David G. Victor, *supra* note 506, at 4.

510. Expert Report of James Sweeney, *supra* note 506, at 60; Expert Report of David G. Victor, *supra* note 506, at 8–10.

government is not responsible for those emissions.[511] Reviewing these materials in the context of the defendants' motion for summary judgment, the district court found "that plaintiffs have provided sufficient evidence showing that causation for their claims is more than attenuated," that "[t]he ultimate issue of causation will require perhaps the most extensive evidence to determine at trial," and that a "final ruling on this issue will benefit from a fully developed factual record where the Court can consider and weigh evidence from both parties."[512]

Thus, even without the "trial of the century," we can see the contours of the "battle of experts" such a trial would entail. Plaintiffs' primary goal with their expert testimony was to establish that the defendant is responsible for a meaningful contribution to climate change—an amount sufficient to prove causal relationships that satisfy the standing requirements and the even more demanding standards for showing a violation of public trust obligations and/or constitutional rights—and that climate change is the legal cause of specific injuries suffered by the plaintiffs. Defendants' primary strategy was to undermine the reliability of plaintiffs' proffers, and their tactic was to poke holes in plaintiffs' expert reports by challenging the science of source attribution and highlighting the importance of confounding factors.

ii. Other Atmospheric Trust Litigation in the U.S.

There have been a number of similar cases asking state courts to find that state governments have a public trust duty to address climate change (frequently referred to as "atmospheric trust" cases).[513] These cases involve the same sort of inquiry into the

511. *See, e.g.*, Federal Defendants' Answer to the First Amended Complaint for Declaratory and Injunctive Relief at ¶ 151, Juliana v. United States, 339 F. Supp. 3d 1062 (D. Or. 2018) ("Federal Defendants aver that from 1850 to 2012, CO_2 emissions from sources within the United States (including from land use) comprised more than 25 percent of cumulative global CO_2 emissions").

512. *Juliana*, 339 F. Supp. 3d at 1062, 1093.

513. *See, e.g.*, Kanuk ex rel. Kanuk v. State Dep't of Nat. Res., 335 P.3d 1088 (Alaska 2014); Sinnok v. Alaska, No. 3AN-17-09910, 2018 WL 7501030 (Alaska Super. Ct. 2018); Butler ex rel. Peshlakai v. Brewer, No. 1 CA–CV 12–0347, 2013 WL 1091209 (Ariz. Ct. App. Mar. 14, 2013); Filippone ex rel. Filippone v. Iowa Dep't of Nat. Res., 829 N.W.2d 589 (Iowa Ct. App. 2013) (declining to extend the public trust doctrine to the atmosphere because the Iowa Supreme Court had previously declined to extend the doctrine to forested areas and public alleyways); Aronow v. State, No. A12–0585, 2012 WL 4476642 (Minn. Ct. App. Oct. 1, 2012) (declining to apply the public trust doctrine to the atmosphere because no court in

extent to which harmful impacts on a public trust resource can be linked to under-regulated greenhouse gas emissions. For example, in *Sanders-Reed v. Martinez*, youth plaintiffs in New Mexico sought a judgment establishing that the state had a public trust duty under state law to protect the atmosphere and that its "failure to investigate the threat posed by climate change" and to devise a plan to "mitigate the effects of climate change" was a breach of that duty.[514] The state district court initially dismissed the case, in part because it determined that New Mexico regulators had properly determined that New Mexico regulation of greenhouse gas emissions "would have no perceptible impact on climate change."[515] The appellate court took a different approach and found that Article XX, Section 21 of the New Mexico state constitution recognizes that a public trust duty exists for the protection of New Mexico's natural resources, including the atmosphere.[516] However, the court also concluded that the state had established legislative and administrative procedures for raising arguments concerning the duty to protect the atmosphere and that these arguments could not be made through a separate common law cause of action.[517] Similarly, courts in Washington State and Alaska have affirmed that those states' public trust doctrines apply to climate change but deferred to existing legislation and executive processes as the appropriate means to regulate GHGs.[518]

Minnesota or any other jurisdiction has done so, and because it had previously held that the public trust doctrine did not apply to land); Chernaik v. Kitzhaber, 328 P.3d 799 (2014); Svitak ex rel. Svitak v. State, 178 Wash. App. 1020, No. 69710–2–I, 2013, 2013 WL 6632124 (Wash. Ct. App. Dec. 16, 2013); Sanders-Reed ex rel. Sanders-Reed v. Martinez, 350 P.3d 1221 (N.M. 2015); Foster v. Wash. State Dep't of Ecology, 362 P.3d 959 (2015).

514. *Sanders-Reed*, 350 P.3d at 1223 (citing plaintiff's amended complaint to district court).

515. Order Granting Defendants' Motion for Summary Judgement and Denying Plaintiffs' Motion for Summary Judgement, Exhibit A, at TR-3, Sanders-Reed ex rel. Sanders-Reed v. Martinez, No. D-101-CV-2011-01514 (N.M. Dist. July 04, 2013).

516. *Sanders-Reed*, 350 P.3d at 1225.

517. *Id.*

518. *Foster*, 362 P.3d 959; Kanuk ex rel. Kanuk v. State Dep't of Nat. Res., 335 P.3d 1088 (Alaska 2014) (ruling that claims for relief raised nonjusticiable political questions); Sinnok v. Alaska, No. 3AN-17-09910, 2018 WL 7501030 (Alaska Super. Ct. 2018).

iii. Foreign Jurisdictions

Similar types of "atmospheric trust" cases have also been brought in foreign jurisdictions to protect rights enumerated in foreign constitutions, human rights instruments, and international treaties. Perhaps most famously, the Supreme Court of the Netherlands recently upheld decisions from the Hague Court of Appeals and the District Court of the Hague in *Urgenda Foundation v. Kingdom of the Netherlands*, finding that the Dutch government had breached its obligations to its citizens by backing away from the previous administration's mitigation commitments, and ordered the government to limit GHG emissions to 25% below 1990 levels by 2020, consistent with what the court viewed as the country's fair contribution towards the U.N. goal of limiting global temperature increases to 2°C above pre-industrial conditions.[519] The Supreme Court supported its decision by referring to IPCC assessments of how climate change is affecting and will affect human and natural systems and an explanation of why the 25% reduction target is necessary to limit global warming to 2°C.[520] Detection and attribution science factored into this analysis in two ways: first, by providing evidence of the harms incurred by Dutch people as a result of climate change (impact attribution); and second, by providing information about the emissions reductions necessary to meet the 2°C target (contribution attribution).

Similar lawsuits have been brought against governments in the United Kingdom,[521] Germany,[522] Canada,[523] Belgium,[524]

519. Urgenda Foundation v. Kingdom of the Netherlands, Hoge Raad, ECLI:NL:HR:2019:2007 (Dec. 20, 2019) [hereinafter *Urgenda* decision (2019)]. (English translation available at http://blogs2.law.columbia.edu/climate-change-litigation/wp-content/uploads/sites/16/non-us-case-documents/2020/20200113_2015-HAZA-C0900456689_judgment.pdf).

520. *Id.* at ¶¶ 2.1, 4.1– 4.8, 7.1–7.3.6.

521. Plan B Earth and Others v. Sec'y of State for Bus., Energy, and Indus. Strategy [2018] EWHC 1892 (Admin), (UK), http://climatecasechart.com/non-us-case/plan-b-earth-others-v-secretary-state-business-energy-industrial-strategy/ [https://perma.cc/KPY8-HPF6].

522. Bundesverfassungsgericht [BVerfG] [Federal Constitutional Court], Nov. 26, 2018, (Germany),http://climatecasechart.com/non-us-case/friends-of-the-earth-germany-association-of-solar-supporters-and-others-v-germany/[https://perma.cc/E3B4-9TF6];Verwaltungsgericht [VG] [Berlin Administrative Trial Court] Oct. 31, 2019, No. 00271/17 R/SP, (Germany), http://climatecasechart.com/non-us-case/family-farmers-and-greenpeace-germany-v-german-government/ [https://perma.cc/4PBK-8DNV].

523. ENVironnement JEUnesse v. Canada, 2018 QCSC 500-06 (Can.), http://climatecasechart.com/non-us-case/environnement-jeunesse-v-canadian-government/ [https://perma.cc/E9NR-EF8D].

Switzerland,[525] India,[526] Pakistan,[527] Colombia,[528] and Uganda,[529] as well as the European Parliament and Council.[530] At the time of this writing, most of these cases are still pending.[531] Four were dismissed by courts on procedural grounds or lack of justiciability

524. Tribunal de Première Instance [Civ.] [Tribunal of First Instance] Brussels, 2016, VZW Klimatzaak v. Kingdom of Belgium, (Belg.), http://climatecasechart.com/non-us-case/vzw-klimaatzaak-v-kingdom-of-belgium-et-al/ [https://perma.cc/E3C9-JWLT].

525. Petition (Summary in English) at ¶ 1(a), Bundesverwaltungsgericht [BVGE] [Federal Administrative Court, Section 1] Nov. 27, 2018, A-2992/2017 (Switz.), http://climatecasechart.com/non-us-case/union-of-swiss-senior-women-for-climate-protection-v-swiss-federal-parliament/ [https://perma.cc/Q2SM-SCEQ].

526. Pandey v. India, (2017) National Green Tribunal, http://climatecasechart.com/non-us-case/pandey-v-india/ [https://perma.cc/VT8P-P6AX].

527. Ali v. Pakistan, Constitutional Petition No. ___ / I of (2016) (SC) (Pak.), http://climatecasechart.com/non-us-case/ali-v-federation-of-pakistan-2/ [https://perma.cc/L228-XQ8T]; Leghari v. Pakistan, (2015) W.P. No. 25501/201 (Lahore High Court) (Pak.), http://climatecasechart.com/non-us-case/ashgar-leghari-v-federation-of-pakistan/ [https://perma.cc/JBN3-XGYJ].

528. Corte Suprema de Justicia [C.S.J.] [Supreme Court], abril 5, 2018, STC4360, No. 11001-22-03-000-2018-00319-01 (Colom.), http://climatecasechart.com/non-us-case/future-generation-v-ministry-environment-others/ [https://perma.cc/53WU-NLJK].

529. Mbabazi and Others v. The Attorney General and National Environmental Management Authority, Civil Suit No. 283 of 2012 (Uganda), http://climatecasechart.com/non-us-case/mbabazi-et-al-v-attorney-general-et-al/ [https://perma.cc/J5RL-U426].

530. Armando Ferrão Carvalho and Others v. The European Parliament and the Council, Case No. T-330/18 (EU General Court 2018), http://climatecasechart.com/non-us-case/armando-ferrao-carvalho-and-others-v-the-european-parliament-and-the-council/ [https://perma.cc/JN4R-3K2Q].

531. Bundesverfassungsgericht [BVerfG] [Federal Constitutional Court], Nov. 26, 2018, (Germany), http://climatecasechart.com/non-us-case/friends-of-the-earth-germany-association-of-solar-supporters-and-others-v-germany/ [https://perma.cc/E3B4-9TF6]; Verwaltungsgericht [VG] [Berlin Administrative Trial Court] Oct. 31, 2019, No. 00271/17 R/SP, (Germany), http://climatecasechart.com/non-us-case/family-farmers-and-greenpeace-germany-v-german-government/ [https://perma.cc/4PBK-8DNV]; Pandey v. India, (2017) National Green Tribunal, http://climatecasechart.com/non-us-case/pandey-v-india/ [https://perma.cc/VT8P-P6AX]; Ali v. Pakistan, Constitutional Petition No. ___ / I of (2016) (SC) (Pak.), http://climatecasechart.com/non-us-case/ali-v-federation-of-pakistan-2/ [https://perma.cc/L228-XQ8T]; Mbabazi and Others v. The Attorney General and National Environmental Management Authority, Civil Suit No. 283 of 2012 (Uganda), http://climatecasechart.com/non-us-case/mbabazi-et-al-v-attorney-general-et-al/ [https://perma.cc/J5RL-U426]; Tribunal de Première Instance [Civ.] [Tribunal of First Instance] Brussels, 2016, VZW Klimatzaak v. Kingdom of Belgium, (Belg.), http://climatecasechart.com/non-us-case/vzw-klimaatzaak-v-kingdom-of-belgium-et-al/ [https://perma.cc/E3C9-JWLT]; Armando Ferrão Carvalho and Others v. The European Parliament and the Council, Case No. T-330/18 (EU General Court 2018), http://climatecasechart.com/non-us-case/armando-ferrao-carvalho-and-others-v-the-european-parliament-and-the-council/ [https://perma.cc/JN4R-3K2Q].

(e.g., due to lack of standing).[532] Decisions have been issued in the Pakistan and Colombia cases holding that the government violated fundamental rights by failing to address the risks posed by climate change (in both cases, the failure to adapt was discussed along with the failure to mitigate emissions).[533] Attribution science plays the same role in these cases as it did in the *Urgenda* decision—supporting claims about impacts and the government's contribution to those impacts.

c. Cases Challenging Permitting and Licensing Decisions

Plaintiffs have also filed cases challenging permitting and licensing decisions that could increase fossil fuel production and/or GHG emissions. For example, petitioners brought a case in Austria alleging that the government's authorization of the Vienna airport expansion would run afoul of emission reductions targets set forth in Austria's Climate Protection Law as well as the country's commitments under the newly enacted Paris Agreement.[534] An administrative court initially held in favor of petitioners, but that decision was overruled by the Austrian Constitutional Court.[535] In Norway, plaintiffs challenged the issuance of licenses for deep-sea

532. Armando Ferrão Carvalho and Others v. The European Parliament and the Council, Case No. T-330/18 (EU General Court 2018), http://climatecasechart.com/non-us-case/armando-ferrao-carvalho-and-others-v-the-european-parliament-and-the-council/ [https://perma.cc/JN4R-3K2Q]; Plan B Earth and Others v. Sec'y of State for Bus., Energy, and Indus. Strategy [2018] EWHC 1892 (Admin), (UK), http://climatecasechart.com/non-us-case/plan-b-earth-others-v-secretary-state-business-energy-industrial-strategy/ [https://perma.cc/KPY8-HPF6]; Bundesverwaltungsgericht [BVGE] [Federal Administrative Court, Section 1] Nov. 27, 2018, A-2992/2017 (Switz.), http://climatecasechart.com/non-us-case/union-of-swiss-senior-women-for-climate-protection-v-swiss-federal-parliament/ [https://perma.cc/Q2SM-SCEQ].
ENVironnement JEUnesse v. Canada, 2018 QCSC 500-06 (Can.), http://climatecasechart.com/non-us-case/environnement-jeunesse-v-canadian-government/ [https://perma.cc/E9NR-EF8D].

533. Leghari v. Pakistan, (2015) W.P. No. 25501/201 (Lahore High Court) (Pak.) http://climatecasechart.com/non-us-case/ashgar-leghari-v-federation-of-pakistan/ [https://perma.cc/JBN3-XGYJ]; Corte Suprema de Justicia [C.S.J.] [Supreme Court], April 5, 2018, STC4360, No. 11001-22-03-000-2018-00319-01 (Colom.), http://climatecasechart.com/non-us-case/future-generation-v-ministry-environment-others/ [https://perma.cc/53WU-NLJK].

534. Verwaltungsgerichtshof [VwGH] [Administrative Court of Justice] Feb. 2, 2017, W109 2000179-1/291E (Autstria), http://climatecasechart.com/non-us-case/in-re-vienna-schwachat-airport-expansion/ [https://perma.cc/BEL8-KWXF].

535. *Id.*; Verfassungsgerichtshof [VfGH] [Constitutional Court] June 29, 2017, E 875/2017, E 886/2017, http://climatecasechart.com/non-us-case/in-re-vienna-schwachat-airport-expansion/ [https://perma.cc/BEL8-KWXF].

oil and gas exploration on similar grounds.[536] The Oslo District Court dismissed the challenge, finding, among other things, that "[e]missions of CO2 abroad from oil and gas exported from Norway are irrelevant" in analyzing the constitutionality of the lease sale;[537] petitioners have appealed that decision. Swedish plaintiffs challenged the sale of coal mines and coal-fired power plants in Germany by Vattenfall—an energy company owned by the Swedish state—again, on similar grounds.[538] The Stockholm District Court denied these requests after determining that the plaintiffs had not experienced an injury from the governmental decisions at issue.[539] Similar lawsuits have been filed in the United Kingdom and Australia.[540] In these types of cases, petitioners can use attribution data to link the emissions generated from the project to harmful effects of climate change.[541] However, as illustrated by the Stockholm District Court's dismissal on standing grounds, it may be more difficult to establish injury based on emissions from specific licensing decisions as compared with cases challenging broader government failures to act on climate change.

536. Greenpeace Nordic Ass'n at 18–19, Case No. 16-166674TVI-OTIR/06, (Oslo District Court, Jan. 4, 2018), http://climatecasechart.com/non-us-case/greenpeace-nordic-assn-and-nature-youth-v-norway-ministry-of-petroleum-and-energy/ [https://perma.cc/7R8N-EW2Q].

537. *Id.* at 21.

538. Tingsrätt [TR] [Stockholm District Court] 2016-09-15 (Sweden), http://climatecasechart.com/non-us-case/push-sweden-nature-youth-sweden-et-al-v-government-of-sweden/ [https://perma.cc/MX84-N5QW].

539. *Id.*

540. *Ironstone Community Action Group Inc. v. NSW Minister for Planning and Duralie Coal Pty. Ltd.*, (2011) NSWLEC 195 (Austl.), http://climatecasechart.com/non-us-case/ironstone-community-action-group-inc-v-nsw-minister-for-planning-and-duralie-coal-pty-ltd/ [https://perma.cc/9YBF-XS5J]; Plan B Earth and Others v. Sec'y of State for Transport, [2019] EWHC 1070 (Admin) (UK),http://climatecasechart.com/non-us-case/plan-b-earth-v-secretary-of-state-for-transport/ [https://perma.cc/N9R8-JBY8].

541. *See, e.g.*, Complaint at 3, Tingsrätt [TR] [Stockholm District Court] 2016-09-15 (Sweden), http://climatecasechart.com/non-us-case/push-sweden-nature-youth-sweden-et-al-v-government-of-sweden/ [https://perma.cc/MX84-N5QW]; Complaint at Section 3.6.1, Verwaltungsgerichtshof [VwGH] [Administrative Court of Justice] Feb. 2, 2017, W109 2000179-1/291E (Autstria), http://climatecasechart.com/non-us-case/in-re-vienna-schwachat-airport-expansion/ [https://perma.cc/BEL8-KWXF]. Plaintiffs in these cases also argued that emissions from the proposed projects would prevent the country from achieving its fair share of emissions reductions as called for in the UNFCCC and the Paris Agreement.

4. Legal Defense of Greenhouse Gas Emission Standards and Related Actions

As governments introduce an increasing number of laws, policies, and programs aimed at addressing the causes and impacts of climate change, the number of lawsuits challenging these actions will also increase.[542] These are similar to lawsuits challenging the failure to regulate greenhouse gas emissions—the key difference being that these lawsuits involve allegations that regulations are *too* stringent or that other actions taken to curtail emissions (e.g., permit denials) are unjustified. Indeed, both types of claims could be, and often are, brought with respect to the same regulatory action, with one side arguing that emission standards are insufficient and another arguing that they are too stringent.[543]

One example of a defense case which involved considerable attention to attribution science was *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie*.[544] In a legal challenge to Vermont's Low Emission Vehicle Program, automobile manufacturers and retailers specifically challenged the scientific basis for the standards, arguing that the program would impose significant costs but "do nothing concrete to improve air quality or the health of Vermont residents."[545] To support this claim, the petitioners emphasized that CO_2 is unlike other air pollutants in that it disperses globally throughout the upper atmosphere and then cited this fact as the

542. *See, e.g.*, Société Arcelor Atlantique et Lorraine v. [EU] Parliament and Council (environment and consumers), Case T-16/04 (EU General Court 2010), http://climatecasechart.com/non-us-case/societe-arcelor-atlantique-et-lorraine-v-eu-parliament-and-council-environment-and-consumers/ [https://perma.cc/VD3V-7VTM]; Essent Belgium NV v. [Flemish region of] Vlaams Gewest, Case C-492/14 (Netherlands 2016), http://climatecasechart.com/non-us-case/essent-belgium-nv-v-flemish-region-of-vlaams-gewest/ [https://perma.cc/JNQ7-N66U]; Maia Filho v. Federal Environmental Agency (IBAMA), Special Appeal 1000.732 – RO (Brazil 2015), http://climatecasechart.com/non-us-case/maia-filho-v-environmental-federal-agency-ibama/ [https://perma.cc/AZ4L-TTM8]; Gloucester Resources Limited v. Minister for Planning, [2019] NSWLEC 7 (Australia 2019), http://climatecasechart.com/non-us-case/gloucester-resources-limited-v-minister-for-planning/ [https://perma.cc/XDW3-WLJY] (in a legal challenge appealing the denial of a company's application to construct a coal mine, an Australian court upheld the government's denial of permit on climate change grounds).

543. *See, e.g.*, Coal. for Responsible Regulation v. EPA, No. 09-1322 (D.C. Cir. Dec 23, 2009); Sierra Club v. EPA, No. 10-1215 (D.C. Cir. Aug 2, 2010) (both challenging EPA's Tailoring Rule).

544. Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie, 508 F. Supp. 2d 295 (D. Vt. 2007).

545. Complaint ¶ 4, *Green Mountain Chrysler*, Dkt. 1, 508 F. Supp. 2d 295 (2:05-cv-302) filed Nov. 18, 2005.

basis for arguing that CO_2 reductions in Vermont would not have any practical impact on public health in Vermont.[546] Vermont, joined by other defendants, solicited expert testimony from scientists to contradict these claims, and the petitioners attacked the credibility of these scientists. The reviewing court issued a lengthy opinion evaluating the scientific claims and finding that the scientific basis for the emission standards was sound.[547] The court cited specific examples of climate-related harms, including potentially severe effects on Vermont, as well as language from the Supreme Court's decision in *Massachusetts* highlighting the legitimacy of small and incremental regulatory steps to address climate change.[548] The decision also contained a lengthy explanation of why expert testimony from climate scientists such as James Hansen was admissible under the *Daubert* test.[549]

5. Lawsuits to Hold Emitters Liable for Damages Caused by Climate Change Impacts

In addition to suing governments for failure to regulate greenhouse gas emissions, some plaintiffs have gone directly to the source, suing major emitters, such as utilities, as well as fossil fuel companies, in an attempt to obtain an injunction against future emissions or monetary damages for adaptation costs. To date, these lawsuits have been predominately domestic, and based on tort or tort-like theories such as public nuisance, private nuisance, and negligence.[550] In one instance, an environmental organization and Philippine citizens filed a petition with the Human Rights Commission of the Philippines claiming that fossil fuel companies' activities constitute a violation of their human rights.[551] In the future, it is possible that climate change lawsuits may be brought by foreign nations or citizens against private actors in either U.S. courts or within their domestic jurisdictions.[552] Attribution science is central to any and all such cases, as it is necessary to establish a causal connection between the defendant's emissions or activities

546. *Id.* at 9–11.
547. *Green Mountain Chrysler*, 508 F. Supp. at 339–40.
548. *See, e.g.*, *id.* at 309.
549. *Id.* at 310–33.
550. Burger & Wentz, *supra* note 8.
551. In re Greenpeace Southeast Asia and Others, Case No. CHR-NI-2016-0001 (2015).
552. *See* Michael Byers et al., *The Internationalization of Climate Damages Litigation*, 7 WASH. J. ENVTL. L. & POL'Y 264 (2017).

and plaintiffs' injuries, and that the injuries were a foreseeable result of the emissions.

Much has been written on the prospect of climate change torts.[553] As others have noted, these analyses sit along a "spectrum," ranging from "those who are optimistic about the prospects for climate damages litigation [and] argue that climate damages are not fundamentally different from other types of common law damages

553. *See* Albert C. Lin & Michael Burger, *State Public Nuisance Claims and Climate Change Adaptation*, 36 PACE ENVTL. L. REV. 49 (2018); Byers et al., *supra* note 552; R. Henry Weaver & Douglas A. Kysar, *Courting Disaster: Climate Change and the Adjudication of Catastrophe*, 93 N.D. L. REV. 295 (2017); CLIMATE CHANGE LIABILITY: TRANSNATIONAL LAW AND PRACTICE (Richard Lord et al. eds., Cambridge University Press 2012); David Weisbach, *Negligence, Strict Liability, and Responsibility for Climate Change*, 97 IOWA L. REV. 521 (2011–2012); CLIMATE CHANGE LIABILITY (Michael Faure & Marjan Peeters, eds., Edward Elgar 2011); Amy Sinden, *Allocating the Costs of the Climate Crisis: Efficiency Versus Justice*, 85 WASH. L. REV. 293, 323–39 (2010); Matthew F. Pawa, *Global Warming: The Ultimate Public Nuisance*, 39 ENVTL. L. REP. 10230 (2009); Christopher R. Reeves, *Climate Change on Trial: Making the Case for Causation*, 32 AM. J. TRIAL ADVOC. 495 (2009); Kirk B. Maag, Note, *Climate Change Litigation: Drawing Lines to Avoid Strict, Joint, and Several Liability*, 98 GEO. L.J. 185 (2009); Randall S. Abate, *Automobile Emissions and Climate Change Impacts: Employing Public Nuisance Doctrine as Part of a "Global Warming Solution" in California*, 40 CONN. L. REV. 591 (2008); Shi-Ling Hsu, *A Realistic Evaluation of Climate Change Litigation Through the Lens of a Hypothetical Lawsuit*, 79 U. COLO. L. REV. 701 (2008); Timothy D. Lytton, *Using Tort Litigation to Enhance Regulatory Policy Making: Evaluating Climate-Change Litigation in Light of Lessons from Gun-Industry and Clergy-Sexual-Abuse Lawsuits*, 86 TEX. L. REV. 1837 (2008); James R. May, *Climate Change, Constitutional Consignment, and the Political Question Doctrine*, 85 DENV. L. REV. 919 (2008); Amelia Thorpe, *Tort-Based Climate Change Litigation and the Political Question Doctrine*, 24 J. LAND USE & ENVTL. L. 79 (2008); Jonathan Zasloff, *The Judicial Carbon Tax: Reconstructing Public Nuisance and Climate Change*, 55 UCLA L. REV. 1827 (2008); Erin Casper Borissov, Note, *Global Warming: A Questionable Use of the Political Question Doctrine*, 41 IND. L. REV. 415 (2008); David A. Dana, *The Mismatch Between Public Nuisance Law and Global Warming*, 18 SUP. CT. ECON. REV. 9 (2010); David Hunter & James Salzman, *Negligence in the Air: The Duty of Care in Climate Change Litigation*, 155 U. PA. L. REV. 1741 (2007); Myles Allen et al., *Scientific Challenges in the Attribution of Harm to Human Influence on Climate*, 155 U. PA. L. REV. 1353 (2007); Daniel J. Grimm, Note, *Global Warming and Market Share Liability: A Proposed Model for Allocating Tort Damages Among CO2 Producers*, 32 COLUM. J. ENVTL. L. 209 (2007); Sarah Olinger, Comment, *Filling the Void in an Otherwise Occupied Field: Using Federal Common Law to Regulate Carbon Dioxide in the Absence of a Preemptive Statute*, 24 PACE ENVTL. L. REV. 237 (2007); Benjamin P. Harper, Note, *Climate Change Litigation: The Federal Common Law of Interstate Nuisance and Federalism Concerns*, 40 GA. L. REV. 661 (2006); Thomas W. Merrill, *Global Warming as a Public Nuisance*, 30 COLUM. J. ENVTL. L. 293 (2005); Matthew F. Pawa & Benjamin A. Krass, *Global Warming as a Public Nuisance:* Connecticut v. American Electric Power, 16 FORDHAM ENVTL. L. REV. 407 (2005); James R. Drabick, Note, *"Private" Public Nuisance and Climate Change: Working Within, and Around, the Special Injury Rule*, 16 FORDHAM ENVTL. L. REV. 503 (2005); Myles R. Allen & Richard Lord, *The Blame Game: Who Will Pay for the Damaging Consequences of Climate Change?*, 432 NATURE 551 (2004); David A. Grossman, *Warming Up to a Not-So-Radical Idea: Tort-Based Climate Change Litigation*, 28 COLUM. J. ENVTL. L. 1 (2003); Eduardo M. Peñalver, *Acts of God or Toxic Torts? Applying Tort Principles to the Problem of Climate Change*, 38 NAT. RESOURCES J. 563 (1998).

that already give rise to liability," to those who "accept that existing legal concepts could form a basis to recover climate damages, [but] they caution that such cases face a series of challenges often centered around causation," to those who "argue that climate damages claims face threshold issues that will likely prevent them from ever being argued on their merits."[554] Among these, Professor Douglas Kysar has done the most to conceptualize and articulate the problems confronting any such claim:

> Tort law seems ill-equipped to address the causes and impacts of climate change: diffuse and disparate in origin, lagged and latticed in effect, anthropogenic greenhouse gas emissions represent the paradigmatic anti-tort, a collective action problem so pervasive and so complicated as to render at once both all of us and none of us responsible. Thus, courts will have ample reason—not to mention doctrinal weaponry—to prevent climate change tort suits from reaching a jury.[555]

This leads Kysar to the conclusion that "tort law is unlikely to play a substantial role in the ultimate effort to reduce greenhouse gas emissions,"[556] placing him on the relatively skeptical end of the spectrum. At the same time, however, Kysar exposes the potential for encounters with climate change tort claims to shift "the bar for exoticism in tort":

> Various suits that have frustrated judges because of their scale, scientific complexity, and widespread policy implications—such as claims involving toxic and environmental harm, tobacco and handgun marketing, or slavery and Holocaust reparations—may come to seem less daunting and intractable when juxtaposed against "the mother of all collective action problems." Current debate over whether courts are engaging in "regulation through litigation" may come to appear miscast in the face of suits that raise at once both an ordinary pollution nuisance and a challenge to the very foundations of modern industrial life. At long last, courts and commentators may come to view tort claims in degrees of polycentricity, rather than in crude binary terms of conventional civil disputes, on the one hand, and political or regulatory matters, on the other.[557]

554. Byers et al., *supra* note 552, at 270–71.
555. Douglas A. Kysar, *What Can Climate Change Do About Tort Law*, 41 ENVTL. L. 1, 4 (2011).
556. *Id.*
557. *Id.* at 4–5.

If the bar shifts, it may well be that the bar shifts not only after but *during* the course of climate tort litigation.[558] To date, Kysar's first prediction, at least, has proved correct. While there have been quite a few successful cases brought against governments for failure to regulate greenhouse gas emissions,[559] the same cannot be said for lawsuits aimed at holding emitters liable for damages caused by climate change impacts. The authors are not aware of any such lawsuit that has been successful to date. Moreover, the influence of these cases on the shape of tort law remains to be seen. But our purposes here are more limited than Kysar's deep conceptualization of tort law: namely, to provide a summary of key issues confronting common law climate change cases and to identify the role attribution science has played, is playing, and might yet play in resolving them.

Accordingly, in this section we describe the basic elements of tort—duty, breach, causation, and harm—and how climate change insinuates itself into an analysis of them. We then assess the role attribution science might play in meeting evidentiary standards in a court of law, and ultimate persuasive outcomes on the merits. Finally, we describe the way attribution science played into a number of high-profile climate tort cases in the past, to give an inkling of what may lie ahead in the future.

a. Elements of Negligence & Nuisance

The legal elements required to prevail on different tort claims differ from one another: to prevail on a negligence claim, the plaintiff must establish that the defendant has breached a duty or standard of care, that this breach caused a personal injury to the plaintiff, and that the defendant's conduct is the "proximate cause" of the injury.[560] To prevail on a private nuisance claim, the plaintiff must establish that the defendant's conduct has caused a "substantial and unreasonable interference with plaintiff's use and enjoyment of property."[561] To prevail on a public nuisance claim,

558. Weaver & Kysar, *supra* note 553; *see also* Douglas A. Kysar, *The Public Life of Private Law: Tort Law as a Risk Regulation Mechanism*, 9 EUR. J. RISK. REG. 48 (2018).

559. *See supra* Part III(C)(3)(a)(i) (Massachusetts v. EPA); *see supra* Part III(C)(3)(c)(iii) (Foreign Jurisdictions).

560. RESTATEMENT (SECOND) OF TORTS § 281 (AM. LAW INST. 1965).

561. RESTATEMENT (SECOND) OF TORTS § 822 (AM. LAW INST. 1979).

the plaintiff must establish that the defendant's conduct has caused an "unreasonable interference with a right common to the public."[562] Despite the differences, they do all share some common elements. The concepts of duty and breach, explicit in negligence, are imported into nuisance through the concept of "unreasonable interference." Proximate causation and a resulting harm or injury are required in all three.

Below, we summarize the key elements of tort cases and briefly touch on how attribution science may help with establishing these elements. This summary is followed by a more in-depth overview of the role of attribution science in climate change cases.

i. Duty

It is a well-worn story that tort law's notion of a legal duty is a confusing, muddled concept, generally bounded by the competing opinions by Judge Cardozo and Judge Andrews set forth in *Palsgraf v. Long Island Railroad Company* some ninety years ago.[563] In Judge Cardozo's view, "antisocial conduct only triggers a duty of tort responsibility when its potential harmful effects can be attached to particular, identifiable victims" and the risk of harm is "apparent to the eye of ordinary vigilance."[564] In other words, "the risk reasonably to be perceived defines the duty to be obeyed, and risk imports relation; it is a risk to another or to others within the range of apprehension."[565] Foreseeability, then, is part of Cardozo's definition of tort duty. In contrast, Judge Andrews' dissent presents a "communal notion of responsibility in which all actors are under a duty to avoid unreasonable behavior, irrespective of whether that behavior implies a particular relation of responsibility to plaintiffs."[566] Judge Andrew explained: "Due care is a duty imposed on each one of us to protect society from unnecessary danger, not to protect A, B, or C alone."[567] For Judge Andrews, the issue of foreseeability of injury to a particular plaintiff may be relevant to the proximate cause inquiry, but not the nature of the

562. Connecticut v. Am. Elec. Power Co., 582 F.3d 309, 369–70 (2d Cir. 2009), *rev'd*, 564 U.S. 410 (2011).

563. Palsgraf v. Long Island R.R. Co., 162 N.E. 99 (N.Y. 1928).

564. Kysar, *supra* note 555, at 13; *Palsgraf*, 162 N.E. at 99.

565. *Palsgraf*, 162 N.E. at 100.

566. Kysar, *supra* note 555, at 14.

567. *Palsgraf*, 162 N.E. at 102.

defendant's duty.[568] Federal and state courts wrestling with cases sounding in negligence and nuisance fall somewhere within this range, with some courts embracing foreseeability of harm to the specific plaintiff as an element of duty[569] and others rejecting it.[570]

The identification of a legal duty under Cardozo's concept is deeply complicated by the facts of climate change. Climate change is, after all, a "geophysical problem . . . centuries in the making (and studying) with causes ranging from volcanoes, to wildfires, to deforestation to stimulation of other greenhouse gases . . . . to the combustion of fossil fuels."[571] What's more, "the range of consequences is likewise universal—warmer weather in some places that may benefit agriculture but worse weather in others, e.g., worse hurricanes, more drought, more crop failures and . . . the melting of the ice caps, the rising of the oceans, and the inevitable flooding of coastal lands."[572] Would the "eye of ordinary vigilance" demanded by Judge Cardozo[573] foresee a pathway leading from a particular activity located somewhere in the "train of industry"[574] to a particular climate change-related injury experienced by a particular person in a particular place and time? Is the duty more easily recognizable if the entity suffering the injury is a state, a city, a tribe, or a certified class? If the particularized harms that come from producing, transporting, storing, marketing, selling, combusting, and/or consuming fossil fuels so as to emit greenhouse gases are foreseeable now, at what point did they become so?

Where foreseeability is an element of tort duty, the history and current and future states of attribution science will play a role in establishing and defending against it. However, even in a case

568. *Id.* at 104.

569. *See, e.g.,* Norris v. Corr. Corp. of Am., 521 F. Supp. 2d 586, 589 (W.D. Ky. 2007).

570. *See, e.g.,* Rodriguez v. Del Sol Shopping Ctr. Assocs., L.P., 326 P.3d 465, 467 (N.M. 2014); Thompson v. Kaczinski, 774 N.W.2d 829, 835 (Iowa 2009). The decisions rejecting foreseeability as an element of duty are consistent with the Third Restatement of Torts, which notes: "Despite widespread use of foreseeability in no-duty determinations, this Restatement disapproves that practice and limits no-duty rulings to articulated policy or principle in order to facilitate more transparent explanations of the reasons for a no-duty ruling and to protect the traditional function of the jury as factfinder." RESTATEMENT (THIRD) OF TORTS: PHYS. & EMOT. HARM § 7, cmt. j (AM. LAW INST. 2010).

571. California v. BP P.L.C., No. C 17-06011 WHA, 2018 WL 1064293 (N.D. Cal. Feb. 27, 2018).

572. *Id.*

573. *Palsgraf*, 162 N.E. at 99.

574. California v. BP P.L.C., 2018 WL 1064293, at *4.

governed by Judge Andrews' more expansive view—for instance, a public nuisance case where the duty is more widely distributed—plaintiffs cannot evade the issue of foreseeability. It will come up in establishing proximate cause. As Kysar explains, "plaintiffs will face the challenge of establishing foreseeability in a way that does not strain liberal notions of limited obligation beyond the breaking point."[575] The end result could be a global duty owed by some select group of actors to people everywhere. Or it could mean that no legal duty exists to constrain these types of behaviors.

ii. Breach

Once a duty has been established, liability can only attach if there has been a breach, in some form, of that duty. The key issue in assessing a breach, under a conventional analysis, involves balancing competing values, both in negligence and nuisance. In the negligence context, a breach occurs where the plaintiff has failed to exercise reasonable care to protect others from a foreseeable risk of harm. What constitutes "reasonable care" is typically defined by what a "reasonable person" would do under similar circumstances.[576] In nuisance, the breach factors into an assessment of whether defendant's interference with plaintiff's person, property, or public goods was "unreasonable." To determine what constitutes an "unreasonable interference," courts may weigh factors such as the utility of the conduct giving rise to the alleged nuisance, the cost of abating the alleged nuisance, and the severity of the harm caused by defendant's conduct when deciding whether the conduct is indeed a nuisance.[577]

In both instances, the "reasonableness" inquiry involves something of a "social welfare cost-benefit test,"[578] with one critical factor being whether the cost of taking precautions is greater or less than the cost of potential harm.[579] Attribution science has a

575. Kysar, *supra* note 555, at 17.

576. RESTATEMENT (SECOND) OF TORTS § 283 (AM. LAW INST. 1965).

577. RESTATEMENT (SECOND) OF TORTS § 826 (AM. LAW INST. 1979). While a balancing of harm versus utility is typically required in nuisance cases seeking injunctive relief, some courts have held that such balancing is not required where plaintiffs are seeking monetary damages. *See, e.g.*, Nat'l Energy Corp. v. O'Quinn, 233 VA. 83, 86 (1982).

578. Kysar, *supra* note 555, at 21.

579. United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947) (liability in negligence will be found if the probability of harm multiplied by the gravity of the potential injury exceeds the cost of precaution).

role to play in calculating the costs of climate change. As discussed in Part II, attribution science is the connective tissue tying particular impacts resulting in particular costs back to climate change and anthropogenic influence on climate change, and it can help improve calculations of the social cost of greenhouse gas emissions.[580]

In some instances, attribution science may have a role to play in calculating the benefits of climate change. As has been long-recognized, climate change does produce some "winners."[581] Changes that lead to increased agricultural production in some northern latitudes may be identified through attribution science. However, many of the benefits of defendants' activities will fall outside the scope of attribution science. These include things like the economic, social, health, and welfare benefits of fossil fuel development, power production, transportation, materials manufacturing, cement, shipping, aviation, and so forth and so on.

Courts will also consider foreseeability when assessing the reasonableness of conduct (a concept that cuts across the elements of duty, breach, and proximate cause). Again, attribution science plays an obvious role in this inquiry, helping to establish that a reasonable person would anticipate that activities which generate greenhouse gas emissions or otherwise contribute to climate change[582] will eventually result in specific types of harmful impacts. But there are limitations on the extent to which attribution science can establish foreseeability with respect to specific impacts and specific plaintiffs, which we discuss in further detail below.

There are other factors underpinning the "reasonableness" analysis that do not implicate climate change attribution science—these include custom, common practice, and regulatory treatment (e.g., whether the conduct is proscribed by law). Thus, while attribution studies can give weight to the idea that major contributions to climate change are "unreasonable," a court may

580. *See also* Kysar, *supra* note 555, at 22–23 (discussing application of SC-CO_2 to *American Electric Power*).

581. *See, e.g.*, J.B. Ruhl, *The Political Economy of Climate Change Winners*, 97 MINN. L. REV. 206 (2012); Michael H. Glantz, *Assessing the Impacts of Climate: The Issue of Winners and Losers in a Global Climate Change Context*, 65 STUD. IN ENVTL. SCI. 41 (1995).

582. Deforestation and the marketing of fossil fuels would be examples of conduct which does not directly generate greenhouse gas emissions but nonetheless contributes to climate change.

nonetheless conclude that such conduct is reasonable because it is a customary pattern of behavior.

iii. Causation

In addition, the plaintiff must show that the defendant's conduct was both the factual and the proximate, or legal, cause of the injury.[583] Factual causation concerns the scientific relationship between the defendant's action or behavior and the alleged injury.[584] To show factual causation, one must show both general, or generic, causation, and specific, or individualized, causation.[585] One commentator offered this useful summary: "General causation refers to whether the action in question *could have* caused the alleged injury, while specific causation refers to whether the action in question 'more likely than not' *actually caused* the alleged injury."[586] These are separate inquiries, that raise distinct questions for attribution science.

In regards to general causation, one critical question is whether and under what circumstances courts will impose liability on an actor who is not the sole cause of the injury. Underpinning this is the question of how courts might apportion liability among multiple emitters. In failure-to-regulate cases, some courts have granted standing based on a showing that the unregulated emissions made a "meaningful contribution" to climate change.[587] Courts have devised alternative tests for apportioning liability in tort cases. Consider the example of "toxic tort" cases, which involve claims of injury caused by exposure to harmful substances, and where there are multiple potential defendants that caused the exposure (e.g., by producing or releasing the harmful substance into the environment).[588] These cases have much in common with tort actions undertaken against greenhouse gas emitters, insofar as there is a "basic problem of proving, even defining, causal relationships in an environment where multiple causation

583. Byers et al., *supra* note 552, at 279.

584. *Id.*

585. *Id.*

586. *Id.*

587. *See supra* Part III(C)(1)(b) (Case Law on Standing to Sue for Climate Change-Related Harms).

588. *See* Glen O. Robinson, *Probabilistic Causation and Compensation for Tortious Risk*, 14 J. LEGAL STUD. 779 (1985).

confounds the possibility of isolating one 'responsible' cause as the touchstone of legal liability."[589]

As in toxic tort cases, there are several ways that liability may be apportioned among potentially responsible parties in this context, including the use of statistical, probabilistic, and epidemiological studies.[590] Due to the nature of the claims in toxic tort cases, it is typically impossible to show that a particular plaintiff's health condition is directly and solely caused by exposure to a substance generated by a specific defendant.[591] To overcome this hurdle, the plaintiffs in toxic tort cases have used statistical analyses and computer modeling to present: (i) probabilistic estimates of health risks associated with chemical exposures, and (ii) relative contributions to that risk from different parties.[592] Where the probability that a particular defendant's substance caused a substantial portion of the harm reaches a certain threshold, then courts may be willing to impose liability for the harm. For example, some courts require plaintiffs to show that their injuries were "more likely than not" caused by the defendant's conduct, and this requirement has been met through showings that the behavior increased the risk of the harm occurring by a factor of 2.[593] However, other courts have held that probabilistic proof is insufficient for imposing liability and have demanded "particularistic proof" of a causal connection.[594]

In regards to specific causation, the critical question is "whether defendant's actions or behavior were 'a necessary element' in bringing about the injury."[595] Assuming one can show that climate change is responsible for a particular local climate-related phenomenon or event that produced an injury, and before one

589. *Id.* at 780.

590. Byers et al., *supra* note 552, at 279.

591. Note, *Causation in Environmental Law: Lessons from Toxic Torts,* 128 HARV. L. REV. 2256, 2259 (2015) ("Because of the nature of the substances generally involved, the harms due to exposure typically are not discovered until long after the exposure occurred. In addition, over that period of time, the injured party may have been exposed to a variety of potentially harmful substances, likely as a result of actions by a variety of different actors. As a result, identifying any responsible party, much less identifying all responsible parties, can be quite difficult.").

592. *Id.* at 2268–69 (citing Daniel Farber, *Toxic Causation,* 71 MINN. L. REV. 1219, 1220 n.7 (1987)).

593. Albert C. Lin, *Beyond Tort: Compensating Victims of Environmental Toxic Injury,*78 S. CAL. L. REV. 1439, 1450 (2005); Grossman, *supra* note 553, at 23.

594. Lin, *supra* note 593, at 1450.

595. Byers et al., *supra* note 552, at 280.

gets to issues of contributory negligence, the problem for proving climate harms here is clear: emissions of any one actor, or even any small set of actors, will be difficult to pin down as a "but-for" cause of impacts arising from anthropogenic climate change.[596]

Again, though, toxic tort law has encountered similar situations—even if at an entirely different scale—and developed approaches through which to assign liability. The "substantial factor" or "material contribution" test allows a court to find liability where a defendant's conduct was a "substantial factor" in bringing about or a "material contribution" to a plaintiff's injury.[597] The "commingled approach" offers another possible approach. In litigation over groundwater contamination from MTBE, a court held that "[w]hen a plaintiff can prove that certain gaseous or liquid products . . . of many suppliers were present in a completely commingled or blended state at the time and place that the risk of harm occurred, and the commingled product caused a single indivisible injury, then each of the products should be deemed to have caused the harm."[598] Under a market share theory of liability, defendants may be held liable for injuries caused by a product based on their respective "shares" in the manufacture and sale of the product.[599]

In contrast to the factual causation inquiry, which focuses on scientific relationships, proximate cause is intended to address whether the injury is sufficiently closely related to the allegedly wrongful conduct, such that it makes sense to impose liability on the defendant.[600] To answer this question, courts may consider factors such as the geographic and temporal proximity between the conduct and the injury (and more generally, the directness of the relationship between conduct and injury), and whether the injury was a foreseeable result of the conduct.[601] As Justice Andrews

596. *See, e.g.* Kysar, *supra* note 555, at 31; Michael Duffy, *Climate Change Causation: Harmonizing Tort Law and Scientific Probability,* 28 TEMP. J. SCI. TECH. & ENVTL. L. 185 (2009).

597. Byers et. al., *supra* note 552, at 281–82.

598. In re Methyl Tertiary Butyl Ether (MTBE) Prod. Liab. Litig., 379 F. Supp. 2d 348, 377–78 (S.D.N.Y. 2005).

599. Byers et al., *supra* note 552, at 283.

600. Another way of posing this question is to ask whether the defendant should be shielded from liability even if he or she is the cause-in-fact of the injury. *See* Luke Meier, *Using Tort Law to Understand the Causation Prong of Standing,* 80 FORDHAM L. REV. 1241, 1249 (2011).

601. KENNETH S. ABRAHAM, THE FORMS AND FUNCTIONS OF TORT LAW 124 (3d ed. 2007). The Supreme Court has held that defendants must establish a direct link between conduct

explained in his *Palsgraf* dissent, "open-ended concepts such as fairness, justice, policy, practical politics, and common sense" may also factor into the proximate cause analysis.[602]

We have already touched on how attribution science can be used to establish causation (in the context of standing) and foreseeability (in the context of duty and breach). A more detailed analysis of the role of attribution science with respect to these two elements is provided in Section III.C.4.b.

iv. Harm or Injury

Regardless of the tort, actual harm must be shown. For a negligence claim, breach must give rise to an injury that is similar to, but not always identical to, the sort of "injury-in-fact" required for standing purposes. Courts have yet to articulate a clear distinction between standing and negligence injuries, but there are some subtle differences in terms of how these concepts are typically defined. For example, most courts have held that negligence liability requires proof of actual harm, whereas standing can be based on a harm that has yet to occur but is imminent.[603] At the same time, the types of harms that can support a negligence claim are defined more broadly to include emotional distress, and in some jurisdictions, this has become a vehicle for imposing liability on defendants whose negligent conduct increases the risk of harm to a plaintiff, thereby causing emotional distress.[604]

and injury to satisfy proximate cause requirements under various statutory frameworks that mirror common law doctrines, and that courts should not go beyond the "first step" of the causal chain to establish that link under these statutes. *See* Bank of Am. Corp. v. City of Miami, 137 S.Ct. 1296 (2017). While directness is certainly relevant to the proximate cause inquiry for tort liability, this narrow interpretation of what qualifies as a sufficient "direct" cause has not been extended to common law cases.

602. David Owen, *Figuring Foreseeability*, 44 WAKE FOREST L. REV. 1277 (2009) (citing *Palsgraf*, 162 N.E. at 103–05 (Andrews, J., dissenting)).

603. Albert Lin, *The Unifying Role of Harm in Environmental Law*, 3 WIS. L. REV. 897, 911 (2006); Cass Sunstein, *Standing Injuries*, 1993 SUP. Ct. REV. 37 (1993).

604. *See* RESTATEMENT (THIRD) OF TORTS: PHYS. & EMOT. HARM § 8, Scope Note (AM. LAW INST. 2012). Courts may require that the emotional injury be linked to some sort of physical harm or impact, such as exposure to a toxic substance, which gives rise to a "reasonable fear" of a physical harm. *See, e.g.*, Sterling v. Velsicol Chem. Corp., 855 F.2d 1188, 1205–06 (6th Cir. 1988) (holding that mental distress from a reasonable fear of cancer is an adequate injury for tort liability under Tennessee law). But some jurisdictions recognize a cause of action for negligent infliction of emotional distress absent any physical impact or injury. *See* Lin, *supra* note 603, at 903–07.

Like negligence, there is some precedent for treating risk as an injury in the context of nuisance claims. Specifically, under the doctrine of "anticipatory nuisance," courts may enjoy an anticipatory or prospective nuisance activity that has not yet caused harm but threatens to do so.[605] In most cases, to prevail on an anticipatory nuisance claim, the plaintiff must show that there is a "high probability" or "reasonable certainty" of injury.[606] Here, again, attribution science would be used in the ways described above—both as a means of characterizing the injury (interference) to the plaintiff, and as a means of explaining why the interference is unreasonable and a threat.

b. Role of Attribution Science

As noted above, attribution science can be used to establish three key elements in tort litigation: foreseeability, causation, and injury. The foregoing discussion of standing illustrates how attribution science is used to establish injury, and while there are subtle differences in how "injury" is defined in standing and on the merits of tort cases, the role of attribution science in these two contexts is roughly the same. We therefore focus here on how attribution science can support findings of foreseeability and causation.

Foreseeability and causation are closely linked—the same research that can be used to establish a causal connection between climate change and impacts can also be used to establish the foreseeability of impacts—but they are not one in the same. To the contrary, there may be circumstances where an impact may have been caused by climate change but was not foreseeable, and circumstances where an impact is a foreseeable consequence of climate change but cannot be causally linked to climate change. It is therefore important to discuss these as distinct applications of attribution science.

With regards to foreseeability: the existing detection and attribution literature highlights a wide array of impacts that are already occurring as a result of climate change and lends credibility to predictions of future impacts. A court's determination as to

605. PROSSER & KEETON ON THE LAW OF TORTS 640-41 (5th ed. 1984); George P. Smith, II, *Re-Validating the Doctrine of Anticipatory Nuisance,* 29 VT. L. REV. 687, 689 (2005).

606. Smith *supra* note 605, at 689; Charles J. Doane, *Beyond Fear: Articulating a Modern Doctrine in Anticipatory Nuisance for Enjoining Improbable Threats of Catastrophic Harm,* 17 B.C. ENVTL. AFF. L. REV. 441 (1990).

whether an impact is a foreseeable consequence of activities that increase greenhouse gas emissions would likely depend on: (i) the degree of confidence with which the impact has been attributed to climate change or projected to occur as a result of climate change; (ii) the amount of scientific research linking the impact to climate change (and level of consensus among scientists); and (iii) the timeframe in which that research was performed. If there are only a handful of studies on a particular impact or if the studies were all published after the allegedly tortious conduct, then courts might conclude that the impacts are not foreseeable.[607]

Establishing that certain physical impacts such as sea level rise and increasing temperatures are foreseeable outcomes of activities that contribute to climate change is a relatively straightforward task. However, as discussed in Part II, the actual injuries associated with climate change are often secondary or tertiary impacts that are influenced by a multitude of confounding factors in addition to anthropogenic influence on climate. The greater the number of confounding factors, the more difficult it may be to establish that a particular injury was foreseeable. It may also be challenging to establish the foreseeability of specific low-probability, high-impact events even where those events are part of a broader trend that has been attributed to or predicted to come about as a result of climate change. For instance, a catastrophic flood that is far more severe than what any climate model predicted may not be foreseeable, even where increased intensity of extreme precipitation events is generally accepted.

In most tort cases invoking climate change, it may be significantly more challenging for plaintiffs to establish causation—and in particular, specific causation—than it is to establish foreseeability. Indeed, this appears to be the most difficult element to prove across all cases. As discussed above, standing law requires a showing of factual or but-for causation. This is also required for

607. Another factor that might be considered in the foreseeability analysis is the scale of the emissions impact—the idea being that a small emissions impact will not result in foreseeable harms. However, technically speaking, even a very small emissions contribution would foreseeability contribute to all impacts associated with climate change due to the dispersion of greenhouse gases in the atmosphere. It is the authors' view that the magnitude of the emissions impact is more relevant to the analysis of harm and causation in the tort context.

negligence and nuisance cases.[608] As with standing, the challenge here is proving a counter-factual: what would have happened in the absence of defendant's conduct? Sometimes this is a relatively easy exercise, but for harms related to climate change, this is a fact-intensive inquiry that can involve a fair amount of assumption and speculation, testimonies from competing experts, and weighing of evidence.[609] Whereas this inquiry is treated as a question of law in the standing context in most cases, it is treated as a question of fact in the tort context, and would therefore be decided "only at the end of trial, after all of the evidence has been received and all of the experts have testified."[610]

The causal questions implicated by tort lawsuits against the range of likely defendants in climate cases are complex. To succeed in such a case, a plaintiff would need to establish several lines of causation:

- The plaintiff must link a specific change or event to anthropogenic climate change (e.g., sea level rise or a flooding event)—i.e., climate change and extreme event attribution.
- The plaintiff must link a specific loss to that change or event (e.g., the cost of adaptation measures or residual losses that were not or could not be avoided through adaptation)—i.e., impact attribution.
- The plaintiff must link the defendant's conduct (i.e., release of greenhouse gas emissions) to anthropogenic climate change and identify the defendant's relative contribution to the harm incurred by the plaintiff—i.e., source attribution.

Regarding the first line of causation: proving that a specific change or event is caused by climate change will be easier for long-term changes such as mean temperature increases and sea level rise—but as discussed in Part II, there are challenges to establishing

608. This is known as "factual causation," "but for causation," or the *sine qua non* test. These are basically the same concepts because "an act is a factual cause of an outcome if, in the absence of the act, the outcome would have occurred even if the defendant had acted non-negligently." RESTATEMENT (THIRD) OF TORTS: LIABILITY FOR PHYS. & EMOT. HARM § 26 Factual Cause (AM. LAW INST. 2012).

609. Luke Meier, *Using Tort Law to Understand the Causation Prong of Standing*, 80 FORDHAM L. REV. 1241, 1248–49 (2011).

610. *Id.* at 1249 (citing KENNETH S. ABRAHAM, THE FORMS AND FUNCTIONS OF TORT LAW 105–07 (3d ed. 2007).

causation even in that context. For example, plaintiffs will need to establish that flooding or saltwater inundation is caused by sea level rise even where coastal erosion and subsidence are also occurring as a result of coastal development.

Linking a specific extreme weather event to climate change poses another test. The probabilistic approach to event attribution, whereby scientists quantify the extent to which anthropogenic climate change affected the probability of the event occurring (expressed as FAR—fraction of attributable risk), would likely be the best vehicle for establishing causation for the purposes of tort litigation.[611] As discussed above, some probabilistic attribution assessments have identified a relatively strong climate signal on certain events with a relatively high level of certainty. For example, the study of the 2003 European Heat Wave found that climate change had increased the probability of this event at least a factor of two, more likely a factor of six.[612] In other studies, the climate signal is evident but less strong. For example, a study of the 2000 United Kingdom floods found that climate change increased the probability of the flood occurring by a factor of two in most simulations, but in 10% of cases, the risk increase was less than 20%.[613]

There is precedent for courts accepting this type of statistical data as evidence of causation. For example, in U.S. tort law, plaintiffs typically must show that their individual injuries were "more likely than not" caused by the behavior question, and this requirement has been met through showings that the behavior increased the risk of the harm occurring by a factor of two.[614] Applying that same standard to the 2003 European Heat Wave, a court could conclude that climate change was "more likely than not" the proximate cause of the heat wave. As discussed in the standing section, courts also consider probabilistic assessments when determining whether a future injury is sufficiently "imminent" such that plaintiffs have satisfied the injury-in-fact requirement.

611. Allen et al., *supra* note 553, at 1385 (citing Myles Allen, *Liability for Climate Change,* 421 NATURE 891, 891–92 (2003); Dáithí A. Stone & Myles R. Allen, *The End-to-End Attribution Problem: From Emissions to Impacts,* 71 CLIMATIC CHANGE 303, 303–04 (2005).

612. Allen et al., *supra* note 553, at 1393.

613. A. Kay et al., *Attribution of Autumn / Winter 2000 Flood Risk in England to Anthropogenic Climate Change; A Catchment-Based Study*, 406 J. OF HYDROLOGY 91 (2011).

614. Grossman, *supra* note 553, at 23.

Probabilistic event attribution can also be supplemented with observational evidence showing trends in the frequency of an event growing over time.[615] Observational evidence of trends probably would not, by itself, suffice for the purposes of establishing liability for a particular event for the reasons noted above. However, it is possible that such evidence could be used to establish liability for the aggregated impacts of additional extreme weather events over time—for example, a state that has experienced a 10% increase in extreme heat days may be able to establish that climate change more likely than not was responsible for that increase. This type of argument has been accepted in the context of the lawsuits noted in the previous sections (defense of government regulation and lawsuits seeking to compel regulation)[616] but has not been tested in the context of private liability lawsuits.

The storyline or mechanistic approach could also be used to link an extreme event or even a long-term change to anthropogenic influence on climate. That approach would yield different types of quantitative findings—for example, that anthropogenic climate change increased the magnitude of a storm or flood by 10%.

Even if the plaintiff is able to establish that a physical change or extreme event was caused by climate change, he or she must also establish the second and third lines of causation. The second causation challenge—establishing and quantifying the specific loss caused by the change or event—involves determining the extent to which the loss was caused by anthropogenic climate change as compared with other confounding factors. As discussed in Part II, a probabilistic approach can also be used in impact attribution to generate this sort of information. However, to date, most impact attribution studies do not produce findings that are as quantitatively robust as studies conducted on extreme events due to the number of confounding factors that influence impacts such as public health outcomes.

The third causation challenge—defining the defendant's relative contribution to the damage—is a matter of source attribution. As discussed above, courts have grappled with a related question in the context of lawsuits challenging government failure to regulate—specifically, whether the total greenhouse gas

615. *See, e.g*, S.K. Min et al., *Human Contribution to More-Intense Precipitation Extremes*, 470 NATURE 378 (2011).

616. *See* Sections III(C)(3) and III(C)(4).

contribution from the unregulated source category is sufficiently large such that: (i) the plaintiffs have standing by virtue of some actual or imminent harm caused by those emissions, and (ii) the government has violated some sort of obligation by failing to regulate those emissions.[617]

Importantly, even if a source's emissions are considered to be a "material", "substantial", or "significant" contribution to climate change, this does not mean that the source caused a specific impact and can therefore be held liable for all harms associated with that impact. Imposing liability in this context would be akin to imposing joint and several liability on all emitters that surpass a materiality threshold—something courts may be reluctant or even unwilling to do, given the possible ramifications of such a judicial policy. Recognizing this, some petitioners are now seeking to obtain monetary damages from emissions sources that are proportional to the emissions contribution from that source.[618]

One possible way to avoid some of the challenges associated with quantifying the defendants' contribution to plaintiffs' injuries is to seek injunctive relief rather than monetary damages in a tort lawsuit. Plaintiffs seeking injunctive relief have thus far faced the same challenges as those seeking monetary relief when attempting to establish causation for standing purposes, but there has not yet been a trial in which courts have fully evaluated the merits of causation claims in either context. Another option for plaintiffs seeking monetary damages would be to rely on lower bound damage estimates that can be attributed to defendants' conduct with high confidence—but this approach might require some re-framing of attribution studies—an issue which we explore in Part IV.

It may also prove easier to establish a causal nexus between defendants' conduct and plaintiffs' injuries where plaintiffs aggregate harms from multiple types of climate change-related impacts and across multiple persons. It is easier to establish, for example, that climate change (and defendants' conduct contributing to climate change) has caused injury to an entire state, city, or trade organization as opposed to an individual private plaintiff.

617. *See* Part III(C)(3)(b).
618. Lliuya v. RWE AG, VG Essen 15.12.2016 (2 O 285/15) (Germany).

c. Cases

i. *Connecticut v. American Electric Power* (Second Circuit)

The Second Circuit's review of *American Electric Power*, discussed above, provides some insights into how courts might handle tort claims pertaining to climate change. First, the court determined that whether a given quantity of emissions is a "meaningful" or "significant" contribution to global climate change is an evidentiary issue that should be addressed at a future stage of the proceedings—at least where those emissions appear on their face to potentially meet that standard.[619] Second, the court found that contributing sources of GHG emissions can be called to account, explaining that "[t]he Court has not imposed a requirement upon all federal common law of nuisance cases that the challenged pollution must be 'directly traced' or that plaintiffs must sue all sources of the pollution complained of in order to state an actionable claim. On the contrary, 'the fact that other persons contribute to a nuisance is not a bar to the defendant's liability for his own contribution.'"[620] Third, the court held that, to prevail on a public nuisance theory, plaintiffs need not demonstrate that they have suffered an actual harm or even an immediate harm—rather, a threatened harm would suffice. The court cited numerous precedents showing that federal courts have the authority to enjoin a threatened nuisance before irreparable harm results.[621] These

619. *Am. Elec. Power*, 582 F.3d at 345.

620. *Am. Elec. Power*, 582 F.3d at 356–57 (citing RESTATEMENT (SECOND) OF TORTS § 840E). (Am. Law Inst. 2008). *See also, e.g.*, Illinois ex. rel Scott v. Milwaukee, No. 72 C 1253, 1973 U.S. Dist. LEXIS 15607, (N.D. Ill. Nov. 1, 1973) ("[I]t is sufficient for plaintiffs to show that defendants' nutrient discharges [leading to eutrophication of Lake Michigan] constitute a significant portion of the total nutrient input to the lake. The correct rule would seem to be that any discharger who contributes an aliquot of a total combined discharge which causes a nuisance may be enjoined from continuing his discharge. Either that is true or it is impossible to enjoin point dischargers."), *aff'd in relevant part and rev'd in part,* 599 F.2d 151 (7th Cir. 1979), *vacated on other grounds*, Milwaukee v. Illinois, 451 U.S. 304 (1981). *Cf.* Student Pub. Interest Research Grp. of N.J., Inc. v. Tenneco Polymers, Inc., 602 F. Supp. 1394, 1397 (D.N.J.1985) (holding, in the context of finding causation for standing purposes, that pollution may derive from multiple sources and that it is not necessary to pinpoint which polluter caused a specific harm).

621. *Am. Elec. Power*, 582 F.3d at 357 (citing Mugler v. Kansas, 123 U.S. 623 (1887) (observing that courts of equity, in adjudicating public nuisance cases, can both prevent threatened nuisances, "before irreparable mischief ensues," as well as abate those in progress); United States v. Ira S. Bushey & Sons, 346 F. Supp. 145, 150 (D. Vt. 1972) ("[o]ne distinguishing feature of equitable relief is that it may be granted upon the threat of harm which has not yet occurred.") (quoting WILLIAM L. PROSSER, HANDBOOK OF THE LAW OF

conclusions would tend to support the notion that a nuisance claim can be predicated on a contribution to threatened harm, and that emitters might be held liable based on their proportional contribution to climate change.

ii. *Kivalina v. Exxon Mobil* (Northern District of California)

The district court's analysis of standing in *Kivalina* also provides some insight into how a court might address a climate nuisance claim. In particular, that the district court found an inadequate causal connection between the defendants' emissions (which were significantly more than those at issue in *AEP*—more than 1.2 billion tons per year of direct emissions) suggests that the district court would not have found adequate causation to support a nuisance claim.[622]

While not explicitly stated in the decision, the court's decision to dismiss the case may have been influenced by the fact that Kivalina was seeking damages to cover the full costs of its injuries, while defendants were only partially responsible for those injuries. In a sense, Kivalina was asking the court to impose joint and several liability on the companies.[623] Consider the following excerpt from the court's discussion of why the political question doctrine (as well as a lack of standing) barred its consideration of the case:

> Plaintiffs also fail to confront the fact that resolution of their nuisance claim requires the judiciary to make a policy decision about *who* should bear the cost of global warming. Though alleging that Defendants are responsible for a "substantial portion" of greenhouse gas emissions . . . Plaintiffs also acknowledge that virtually everyone on Earth is responsible on some level for contributing to such emissions. Yet, by pressing this lawsuit, Plaintiffs are in effect asking

TORTS 624 (3d ed. 1964)); Texas v. Pankey, 441 F.2d 236, 242 (10th Cir. 1971) (reversing district court refusing to issue injunction against pesticide spraying that was both threatened at the time the suit was instituted and had since been done); 7 STUART M. SPEISER, CHARLES F. KRAUSE & ALFRED W. GANS, THE AMERICAN LAW OF TORTS § 20.19 (Thomson West 2003) ("We deem it necessary to explain that a prospective nuisance is a fit candidate for injunctive relief. . . . One distinguishing feature of equitable relief is that it may be granted upon the threat of harm which has not yet occurred."); Andrew H. Sharp, Comment, *An Ounce of Prevention: Rehabilitating the Anticipatory Nuisance Doctrine,* 15 B.C. ENVTL. AFF. L. REV. 627, 633–36 (1988).

622. Native Vill. of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863, 881 (N.D. Cal. 2009), *aff'd,* 696 F.3d 849 (9th Cir. 2012).

623. However, courts might not be receptive to such claims. *See* Maag, *supra* note 553, at 187.

> this Court to make a political judgment that the *two dozen Defendants named in this action should be the only ones to bear the cost of contributing to global warming*. Plaintiffs respond that Defendants *should be* the ones held responsible for damaging Kivalina allegedly because "they are responsible for more of the problem than anyone else in the nation . . ." [] But even if that were true, Plaintiffs ignore that the allocation of fault—and cost—of global warming is a matter appropriately left for determination by the executive or legislative branch in the first instance.[624]

iii. *Lliuya v. RWE AG*

For plaintiffs seeking damages, an alternative approach to *Kivalina* is to request compensation for a proportion of damages that corresponds with the proportion of global greenhouse gas emissions emitted by the defendant. This is the strategy deployed in *Lliuya v. RWE AG*, in which a Peruvian farmer filed suit in German court against a German utility company, seeking damages to offset the costs of protecting his town from melting glaciers.[625] The farmer only sought damages proportional to the utility's relative contribution to global GHG emissions.[626] A district court in Germany dismissed the case, finding that there was no "linear causal chain" between RWE's emissions and the alleged injury because so many emitters had contributed to the risk of flooding in the farmer's town,[627] but the appellate court reversed and directed that the case move forward to an evidentiary phase to determine whether the plaintiff's home is threatened by flooding or mudslide as a result of the melting glacier, and the extent to which RWE's greenhouse gas emissions contribute to that risk.[628] The court will be reviewing expert opinions on the RWE's CO_2 emissions, the contribution of those emissions to climate change, the resulting impact on the glacier, and RWE's contributory share of responsibility for causing that impact.

624. Native Vill. of Kivalina, 663 F. Supp. 2d at 876–77.

625. *Lliuya v. RWE*, *supra* note 618.

626. *Id.*

627. FRANKFURTER ALLGEMEINE ZEITUNG [*David Loses the Fight Against Goliath*], Dec. 15, 2016, https://www.faz.net/aktuell/wirtschaft/energiepolitik/peruanischer-bauer-scheitert-mit-klage-gegen-rwe-14575835.html [https://perma.cc/3JNZ-9ADV] ("Eine Flutgefahr wäre jedoch der RWE AG nicht individuell zuzuordnen." ["A flood risk would however not be attributed singly to RWE AG."]).

628. Lliuya v. RWE AG, Landgericht Essen 30.11.2017 (I-5 U 15/17) (Germany).

Providing an accurate and precise estimate of a particular emitter's contribution to climate change remains challenging—in part due to limited information about historical and current emissions from individual sources, and in part due to uncertainty about the total amount of emissions being generated and sequestered as well as the relative contribution of different greenhouse gases to the greenhouse effect. There is also the question of how to apportion responsibility for emissions, with one critical question being whether fossil fuel production companies, electric generating units, or both should be viewed as "responsible" for emissions in the context of a private liability lawsuit. While this is an "attribution" question, it does not fall within the scope of detection and attribution science; rather, it involves social, political, and legal determinations about how to apportion responsibility.

iv. Pending U.S. Cases Against Fossil Fuel Companies

In 2017 and 2018, local governments across the United States initiated a new wave of litigation seeking to hold fossil fuel companies liable for their contribution to climate change and to recover damages for the cost of adapting to climate change.[629] Similar lawsuits have been filed by Rhode Island and the Pacific Coast Federation of Fishermen's Associations.[630] The plaintiffs in these cases allege that companies like ExxonMobil, BP, and Shell knowingly contributed to climate change by extracting and selling fossil fuels, obscuring the science of climate change, and fighting policies aimed at mitigating climate change, and should therefore

629. Complaint, City of Imperial Beach v. Chevron Corp., No. C17-01227 (Cal. App. Dep't Super. Ct. Jul. 17, 2017); Complaint for Public Nuisance, City of Oakland v. BP P.L.C., No. RG17875889 (Cal. App. Dep't Super. Ct. Sep. 19, 2017); Complaint, City of Santa Cruz v. Chevron Corp., No. 17CV03243 (Cal. App. Dep't Super. Ct. Dec. 20, 2017); Complaint, Cty. of Marin v. Chevron Corp., No. CIV1702586 (Cal. App. Dep't Super. Ct. Jul. 17, 2017); Complaint, Cty. of San Mateo v. Chevron Corp., No. 17CIV03222 (Cal. App. Dep't Super. Ct. Jul. 17, 2017); Complaint, Cty. of Santa Cruz v. Chevron Corp., No. 17CV03242 (Cal. App. Dep't Super. Ct. Jul. 17, 2017); Complaint for Public Nuisance, City of San Francisco v. BP P.L.C., No. CGC-17-561370 (Cal. App. Dep't Super. Ct. Sep. 19, 2017); Complaint, City of Richmond v. Chevron Corp., No. C18-00055 (Cal. App. Dep't Super. Ct. Jan. 22, 2018); Complaint and Jury Demand, Bd. of Cnty. Comm'rs of Boulder Cty. v. Suncor Energy (U.S.A.), No. 2018CV030349 (Colo. Dist. Ct. Apr. 17, 2018); Complaint, City of New York v. BP P.L.C., No. 1:18-cv-00182 (S.D.N.Y. Jan. 9, 2018); Plaintiff's Complaint, Mayor & City of Baltimore v. BP P.L.C., No. 24-C-18-004219 (Md. Cir. Ct. Jul. 20, 2018).

630. Complaint, Rhode Island v. Chevron Corp., No. PC-2018-4716 (R.I. Super. Ct. Jul. 2, 2018); Complaint, Pac. Coast Fed'n. of Fishermen's Ass'ns, Inc. v. Chevron Corp., No. CGC-18-571285 (Cal. Super. Ct. Nov. 14, 2018).

be held liable for some of the adaptation costs incurred by governments. They are pursuing multiple state law legal theories: public nuisance, private nuisance, negligence, trespass, failure to warn, and design defect, among others. These are not the first tort cases against emitters involving state rather than federal law claims—as noted in the above discussion of standing,[631] both *American Electric Power* and *Comer* also involved state law claims, but those decisions did not address the merits of those claims.

The complaints submitted by petitioners in these cases touch on all aspects of attribution. They discuss the basic science of climate change and attribution of climate change to increasing concentrations of greenhouse gas emissions; they identify specific extreme events and impacts of climate change that are injuring petitioners; and they examine "known causes" of those impacts, looking at the effect of anthropogenic climate change as well as other factors.[632] With regards to source attribution, petitioners quantify the cumulative emissions from the fossil fuels produced, sold, and marketed by defendant companies (e.g., "15% of global fossil fuel product-related CO2 between 1965 and 2015, with contributions currently continuing unabated"[633]) and assert that this is a "substantial" contribution to the impacts on petitioners.[634] The complaints are thus drafted in a manner which clearly anticipates that questions of climate change attribution will be at the heart of the inquiry into whether defendants have caused a nuisance or other actionable harm under common law. The attribution statements contained therein are relatively robust because: (i) petitioners represent the aggregated interests of all individuals within their jurisdiction (or trade association) and can therefore allege a broader array and greater magnitude of harms, and (ii) emissions from the combustion of fossil fuels produced by defendants constitute a relatively large (and quantifiable) share of global cumulative emissions. From the standpoint of attribution

631. *See supra* Section III (C)(1).

632. *See, e.g.*, Complaint for Public Nuisance, City of San Francisco v. BP P.L.C., *supra* note 629; Plaintiff's Complaint, Mayor & City of Baltimore v. BP P.LC., *supra* note 629; Complaint, Rhode Island v. Chevron Corp., *supra* note 630.

633. Complaint for Public Nuisance, City of San Francisco v. BP P.L.C., *supra* note 629, at 35.

634. *See, e.g.*, Complaint, Rhode Island v. Chevron Corp., *supra* note 630, at 48; Complaint for Public Nuisance, City of San Francisco v. BP P.L.C., *supra* note 629, at 35; Complaint, Maryland & Mayor of Baltimore v. BP P.L.C., *supra* note 629, at 49.

science, petitioners have made compelling arguments as to why a substantial proportion of their injuries can be traced to those emissions.

It remains unclear whether these cases will actually go to trial and whether the reviewing courts will fully evaluate the attribution questions presented therein. While plaintiffs are pursing state law theories, defendants have argued (and some judges have agreed) that all of the claims are "necessarily governed by federal law" because a "uniform standard of decision is necessary to deal with the issues raised" by plaintiffs.[635] Cases decided under federal law are more likely to be dismissed due to federal precedent in cases such as *American Electric Power*. To date, two cases have been dismissed by district court judges who held that claims were non-justiciable because they raised questions that should be resolved by the legislative and executive branches of the federal government.[636] One of these federal judges held a "climate science tutorial" in which both sides were asked to brief him on climate science. However, the opinion granting defendants' motion to dismiss explicitly recognized that "[t]he issue is not over science" but rather precedent and the separation of powers.[637]

v. Philippines Carbon Majors Inquiry

Plaintiffs in foreign jurisdictions have also begun to use human rights law and other legal sources as the basis for holding companies responsible for their contribution to climate change. In 2016, environmental and human rights advocates submitted a petition to the Philippines Commission on Human Rights requesting an investigation into the responsibility of forty-seven "Carbon Majors" (carbon producing companies) for human rights violations or threats of violations resulting from the impacts of climate change.[638] The claims raised by petitioners are similar to those raised in tort—that the companies produced and promoted the use of massive quantities of fossil fuels with full knowledge that the consumption of these fuels would contribute significantly to

635. City of Oakland v. BP P.L.C., No. C 17-06011 WHA, 2018 WL 1064293, at *3 (N.D. Cal. Feb. 27, 2018).

636. City of Oakland v. BP P.L.C., 325 F. Supp. 3d 1017 (N.D. Cal. 2018); City of New York v. BP P.L.C., 325 F. Supp. 3d 466 (S.D.N.Y. 2018).

637. City of Oakland v. BP P.L.C., 325 F. Supp. at 1022 (N.D. Cal. 2018).

638. In re Greenpeace Southeast Asia v. Chevron, Case No. CHR-NI-2016-0001 (2016).

global climate change (and the corresponding harmful impacts on lives and livelihoods), and that this knowing contribution constituted a violation of fundamental human rights.[639] The petition emphasizes the scientific basis for the claim, referring to scientific studies on climate change attribution as well studies on the emissions that can be attributed to the carbon majors. A joint summary brief submitted by a group of amici curiae in support of the petitioners contains an even more detailed overview of climate and attribution science, including the latest research on how climate change is affecting and will continue to affect the Philippines.[640] The joint summary brief was a collaboration between legal experts and climate scientists—the goal being to present a credible overview of the best available science in relatively straightforward terms. In December 2019, the Commission announced its finding that major fossil fuel companies can be held liable for climate change impacts and that existing civil law in the Philippines provided grounds for holding such companies criminally liable where there is clear proof that they have engaged in acts of obstruction, deception, or fraud.[641]

d. Concluding Notes on Tort Liability

The role of attribution science in climate torts is, at the moment, front and center in the public's eye. But our analysis is consistent with Professor Kysar's:

> Make no mistake: a conceivable set of arguments on behalf of climate change tort plaintiffs *does* exist. The problem, however, is that the winning scenario for most climate-related harms requires a court to stretch in plaintiffs' direction at nearly every stage of the traditional tort analysis: duty would have to encompass "negligence in the air," rather than more particularized relations of responsibility; nuisance would have to be interpreted as an absolute protection against significant invasions, irrespective of social welfare balancing; actual cause would have to embrace—at long last—a probabilistic, risk-

639. *Id.*

640. CENTER FOR INTERNATIONAL ENVIRONMENTAL LAW ET AL., JOINT SUMMARY OF THE AMICUS Brief CURIAE: IN RE: NATIONAL INQUIRY ON THE IMPACT OF CLIMATE CHANGE ON THE HUMAN RIGHTS OF THE FILIPINO PEOPLE (Mar. 19, 2018), https://www.ciel.org/philippines-joint-amicus [https://perma.cc/66P4-KBU7].

641. Press Release, CIEL, Groundbreaking Inquiry in Philippines Links Carbon Majors to Human Rights Impacts of Climate Change, Calls for Greater Accountability (Dec. 9, 2019).

> enhancement conception of causation; exceptional measures of apportionment would have to be invoked to address a multiple defendant problem of unprecedented magnitude; proximate cause would have to be interpreted such that the scope of foreseeable harm from greenhouse gas emissions both tracks projections from climate models that stand at the very forefront of scientific inquiry and, in many cases, applies retroactively as a form of imputed knowledge tantamount to strict liability; and harm would have to be expanded to include much more by way of anticipatory injury than courts currently recognize.[642]

Science can be used to support arguments but it does not necessarily answer fundamental questions over the appropriate logic of blame.

6. Lawsuits Involving Climate Change Impacts, Adaptation, and Risk Disclosures

Attribution science also plays a more limited role in lawsuits involving climate change impacts, adaptation, and disclosures about climate change-related risks. These include: (i) failure-to-adapt lawsuits, which involve allegations that an actor has failed to account for the effects of climate change and this resulted in an adverse outcome that would not have occurred if the actor had accounted for those effects, or else failed to develop adequate plans to prevent foreseeable adverse outcomes in the future;[643] (ii) lawsuits involving legal defense of adaptation measures;[644] (iii) lawsuits in which defendants seek to shield themselves from liability for climate-related harms by alleging that climate change, and not their own conduct, was responsible for those harms;[645] and (iv)

642. Kysar, *supra* note 555, at 44.

643. *See, e.g.*, ExxonMobil Complaint for Declaratory and Injunctive Relief and Civil Penalties at para 170; Conservation Law Found. v. Exxon Mobil Corp., No. 1:16-cv-11950 (D. Mass. Sep. 9, 2016); Complaint and Jury Demand, Conservation Law Foundation, Inc. v. Shell Oil Products US, No. 1:17-cv-00396 (D.R.I. Aug. 28, 2017). *See also* Jennifer Klein, *Potential Liability of Governments for Failure to Prepare for Climate Change*, SABIN CENTER FOR CLIMATE CHANGE LAW (2015); Jacqueline Peel & Hari M. Osofsky, *Sue to Adapt?,* 99 MINN. L. REV. 2177, 2193–95 (2015).

644. *See, e.g.*, cases cited *supra* note 643.

645. For example, utilities may cite climate change as a defense in wildfire litigation. *See* Mark Chediak, *Facing $17 Billion in Fire Damages, a CEO Blames Climate Change,* BLOOMBERG (August 13, 2018), https://www.bloomberg.com/news/articles/2018-08-13/facing-17-billion-in-fire-damages-a-ceo-blames-climate-change [https://perma.cc/9A38-YQUD].

lawsuits involving climate change-related risk disclosures in contexts, such as environmental reviews and financial statements.[646]

One critical question in such cases is whether the present or future effects of climate change are foreseeable. This bears on questions such as whether it was reasonable for a defendant to omit climate change-related risks from a security disclosure or an environmental report; whether it was reasonable for a defendant to ignore climate change-related risks in the approval, construction, or operation of a facility or development project; and whether it was reasonable for a government officer to impose new restrictions on private development due to climate change-related risks. For example, attribution science has been used in cases involving listing decisions under the U.S. Endangered Species Act ("ESA") to both justify listing decisions predicated on consideration of climate change-related risks to the species[647] and to compel consideration of climate change impacts where the government failed to do so in listing decisions.[648] Attribution science may also be used to

646. *See, e.g.*, AquAlliance v. Bureau of Reclamation, F. Supp. 3d 969 (E.D. Cal. 2018) (agency violated NEPA by failing to adequately assess climate change impacts on water supply); Sierra Club v. FERC, 867 F.3d 1357 (D.C. Cir. 2017) (agency violated NEPA by failing to adequately disclose GHG emissions from pipeline project); People of the State of New York v. Exxon Mobil Corp., N.Y. No. 452044 (Dec. 10, 2019) (Exxon did not violate Martin Act through public disclosures concerning how it accounted for past, present, and future climate change risks). *See also* Michael Burger & Jessica Wentz, *Downstream and Upstream Emissions: The Proper Scope of NEPA Review*, 41 HARV. ENVTL. L. REV. 109 (2017); Jessica Wentz, *Planning for the Effects of Climate Change on Natural Resources,* 47 ENVTL. L. REP. 10220 (March 2017); Jessica Wentz, *Assessing the Impacts of Climate Change on the Built Environment: A Framework for Environmental Reviews*, 45 ENVTL. L. REP. 11015 (2015).

647. *See, e.g.*, Alaska Oil & Gas Ass'n v. Pritzker, 840 F.3d 671 (9th Cir. 2016) (upholding NMFS's use of climate science in deciding to add Pacific bearded seal subspecies to endangered species list); Alaska Oil & Gas Ass'n v. Jewell, 815 F.3d 544, 558, 46 ELR 20042 (9th Cir. 2016) (upholding FWS's decision to account for climate change impacts in designating critical habitat for species); In re Polar Bear Endangered Species Act Listing & §4(d) Rule Litig., 794 F. Supp. 2d 65, 41 ELR 20318 (D.D.C. 2011), *aff'd*, 709 F.3d 1, 43 ELR 20132 (D.C. Cir. 2013) (upholding the polar bear listing); Ctr. for Biological Diversity v. Lubchenco, 758 F. Supp. 2d 945 (N.D. Cal. 2010) (upholding NMFS decision not to list ribbon seal as threatened or endangered despite climate-related threats).

648. *See, e.g.*, Defs. of Wildlife v. Jewell, No. 14-247-M-DLC, 2016 WL 1363865, at *20, 46 ELR 20070 (D. Mont. Apr. 4, 2016) (FWS failed to use best available science, including science on climate change, when deciding not to list wolverine as threatened); In re Polar Bear Endangered Species Act Listing §4(d) Rule Litig., 748 F. Supp. 2d 19, 30 (D.D.C. 2010) (holding that a species may be listed as "endangered" even if it is not in danger of imminent extinction, and remanding FWS's decision to list the polar bear as "threatened" rather than "endangered" for additional consideration of foreseeable future threats, particularly changes in future sea ice conditions); Ctr. for Biological Diversity v. Zinke, No. 3:18-cv-00064-SLG,

establish the extent to which anthropogenic climate change is the cause of harmful effects, which bears on the question of whether the defendant's failure to adapt actually caused or contributed to the plaintiff's alleged injury.

IV. FUTURE DIRECTIONS IN THE LAW AND SCIENCE OF CLIMATE ATTRIBUTION

As courts and policy-makers continue to grapple with appropriate responses to the increasingly urgent climate crisis, attribution science will continue to play a critical role in shaping discussions around responsibility and liability for climate change and its impacts. Here, we discuss future directions in the law and science of climate change attribution, addressing questions such as how attribution science might better support policy-making, planning and litigation; how plaintiffs might utilize attribution science in lawsuits against government and private defendants; and how defendants and courts might respond to the realities and limitations of climate attribution science. Some of these functions may be best performed by a third party organization that focuses on the synthesis and communication of scientific research, such as the Intergovernmental Panel on Climate Change.[649]

A. How Can Attribution Science Better Support Climate Law, Policy and Planning?

There are a variety of ways in which the scientific community could work towards supporting applications of attribution research, such as the use of this research to inform loss and damage negotiations and judicial determinations of liability for climate change impacts. These include: (i) continuing to lead the development of scientific knowledge and understanding by

2018 WL 8805325, at *1 (D. Alaska 2018) (challenging the determination that the listing of the Pacific walrus as endangered or threatened was not warranted).

649. The IPCC chapters on detection and attribution of climate change are a good example of how attribution research can be summarized, synthesized, and communicated in an accessible format. Krishna Mirle Achuta Rao et al., *Detection and Attribution of Climate Change: from Global to Regional*, *in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 867–952 (2013). Other entities that are engaged in the synthesis and communication of attribution research include the World Weather Attribution (WWA) project and the Bulletin of Atmospheric Scientists (particularly in the publication of the annual reports on extreme event attribution).

advancing detection and attribution research across the board; (ii) generating attribution findings at different confidence levels to better communicate uncertainty about the "upper bound" and "lower bound" of plausible anthropogenic influence on an observed change; (iii) communicating findings clearly and in an accessible format; (iv) engaging stakeholders; and (v) linking individual studies to other advancing research areas that helps to flesh out the causal chain from emissions to impact.

1. Continue to Conduct Attribution Research on the Full Range of Climate Change Impacts With An Eye Towards Improving Confidence Levels and Certainty In Findings

The body of attribution research has grown considerably in recent years, increasing levels of confidence and certainty regarding a wide range of climate impacts at multiple political and geographical scales. Climate scientists pursuing their collective and independent research agendas have already established an undeniable connection between anthropogenic GHG emissions and climate change, and between climate change and slow onset impacts and the increasing frequency and intensity of certain types of extreme events, assuring that there is a sound scientific basis for collective action to address the climate crisis through mitigation and adaptation measures. More recent emphasis in relatively novel areas such as source attribution and single-event attribution has already helped inform progressive advocacy strategies. So, in an important sense, the single most important thing the scientific community can do to support applications of attribution research is *more of the same*.

Indeed, international and national policy initiatives, as well as lawsuits in the United States and elsewhere, have relied on existing attribution research to claim that climate change is responsible for a broad range of impacts, including coastal impacts from sea level rise, loss of snowmelt, declines in agricultural productivity, and declines in fishery productivity, among other things. To our knowledge, international coordination, domestic efforts, and climate change litigation have never failed due to a shortfall in the attribution science—even despite a concerted disinformation campaign that has reduced political support for ambitious climate action for the last quarter century.[650] In short, the scientific findings compiled to date are already well-suited to support climate law and policy.

Yet, there are gaps in coverage, particularly with respect to extreme events and impacts in developing countries and in areas where the observational record is not as robust and where funding for research may be more limited. Moreover, even where attribution research has been performed for a particular variable, the scope and scale of the study may be incompatible with real-world applications. Geographic and temporal scope are both relevant in this context. For example, loss and damage negotiations would benefit from research attributing impacts over a long timeframe within specific countries, whereas the plaintiffs in a case like *Juliana*[651] would benefit most from research attributing impacts on them as individuals, which requires more downscaling than a country-wide analysis and a more complete reckoning with confounding factors.

Going forward, litigants, policy-makers, and planners will benefit from attribution research on all impacts and at all scales from the global to the highly individualized, the goal being to improve confidence levels and certainty in findings. It will be helpful for scientists to generate additional findings for slow-onset impacts such as sea level rise, temperature changes, ocean acidification, and desertification, as well as extreme events such as precipitation, heat, and wildfire. It would additionally be beneficial to work towards quantifying actual impacts or harms on communities and individuals.

The scientific community could work with affected stakeholders to address the incomplete coverage of attribution science and identify priority areas for research. Granted, working with affected people to determine what variables to focus on in attribution studies could contribute to concerns about selection bias (i.e., the bias introduced when data is selected for research without proper randomization). This practice could result in a larger proportion

650. *See* Fossil Free MIT, *The Fossil Fuel Industry's Role in Hindering Climate Change Action: Lobbying and Disinformation Against Science and Scientists* (April 2014) https://www.fossilfreemit.org/wp-content/uploads/2014/08/FossilFreeMIT-Lobbying-Disinformation.pdf [https://perma.cc/X8DD-S6ED]; Union of Concerned Scientists, *Climate Disinformation*, https://www.ucsusa.org/climate/disinformation [https://perma.cc/4976-NSKS].

651. 339 F. Supp. 3d 1062.

of attribution studies that focus on events or impacts with a clear connection to climate change than a purely random sampling of events and impacts. As such, scientists may need to be cautious about any overarching statements made with respect to the body of attribution research. But scientists are already cautious about making such statements,[652] and such concerns about selection bias would not undermine the credibility of the individual studies being performed.

2. Generate Findings at Different Confidence Levels

As discussed in Part II, attribution findings are often expressed in terms of probabilities and confidence levels. For example, an IPCC report might conclude with "high confidence" (80%) that a particular impact was "very likely" caused by anthropogenic climate change, or a probabilistic event attribution study might find with > 90% confidence that anthropogenic climate change quadrupled the risk of a particular storm occurring. These are compelling statistics, but depending on the application, it may also be helpful for researchers to also discuss lower-bound, higher confidence estimates (e.g., > 95% confidence that anthropogenic climate change at least doubled the risk of that same storm occurring) or higher-bound, lower confidence estimates (e.g., > 80% confidence that anthropogenic climate change made the storm at least six times more likely). Lower-bound estimates with higher confidence levels would be more useful for applications where certainty in findings is needed, such as litigation seeking to hold fossil fuel companies liable for their contribution to climate change. Upper-bound estimates with lower confidence levels would be more useful in policy and planning applications where decision-makers would benefit from understanding the potential extent of anthropogenic influence on an observed change but certainty about that data is less important.

There is an inevitable tradeoff between the level of confidence in findings and the magnitude of the "human fingerprint" identified in an attribution study. Scientists can issue higher confidence findings that anthropogenic climate change contributed "at least" a certain amount to the probability or magnitude of an event without

652. *See, e.g.*, BAMS 2016, *supra* note 76 (studies contained within these reports contain clear explanations of research parameters and uncertainty).

ruling out the possibility that the effect of anthropogenic climate change was actually much larger. Again, discussing both lower and upper bound estimates in this context is helpful for navigating uncertainty and clarifying findings. Consider the study of the 2003 European heat wave: Stott et al. (2004) found that it was very likely (confidence level > 90%) that anthropogenic climate change had at least doubled the risk of a heat wave of the sort experienced that summer (FAR = 0.5), but they also noted that the anthropogenic FAR could be substantially greater and that their "best estimate" was that climate change had increased the risk by a factor of four (FAR = 0.75) (no confidence interval was specified for this estimate, but it was clearly lower than 90%).[653] Without that additional information, a reader might assume that the FAR = 0.50 is the "best estimate" of the human fingerprint in this study, and without the more conservative FAR estimate, the findings might not hold up to scientific (or judicial) scrutiny.

This same approach could also be implemented in the context of a storyline or mechanistic study. For example, a storyline evaluation of a tropical storm might generate several findings at different confidence intervals (e.g., >95% chance that climate change increased the magnitude of a storm by at least 30%, >90% chance that climate change increased the magnitude of the storm by at least 40%, and >80% chance that climate change increased the magnitude of the storm by at least 50%).

3. Clearly Communicate Findings

Most attribution studies are written for a scientific audience, and the findings contained therein can be difficult to understand for people who lack expertise with terminology and concepts such as confidence intervals and p-values. These studies are sometimes "translated" for a broader audience, often by journalists, but when non-scientists summarize scientific findings there is a greater risk that complex topics will be over-simplified or inaccurate conclusions will be drawn from the research. For this reason, it is helpful for the scientists conducting the research to present their findings in a clear and accessible fashion, to the extent practicable.

Marjanac et al. (2017) highlight several best practices for communicating attribution science to courts, but their

653. Stott et al., *supra* note 153.

recommendations apply in equal force to communication with policy-makers, planners, companies, and the public at large:

> (i) areas of agreement should be clearly stated before discussion of areas of disagreement; (ii) methodology and results should be quantitatively and qualitatively transparent to enable interpretation and assessment of credibility by the courts; (iii) assumptions and uncertainties should be stated in a simple, concise and transparent manner; and (iv), results should discuss implications for foreseeability; that is, whether and to what extent a study can opine on the impact of anthropogenic emissions on the future likelihood of occurrence or severity of the event.[654]

An oft-lamented reality is that in communicating uncertainty, bias, and other limitations in their research, scientists risk giving the impression that the research is not credible or accurate. Careful communication of these concepts is also important to protect the credibility of the research against external attacks by parties antagonistic to climate action, or else defending themselves in lawsuits. Generally speaking, careful communication involves providing context for statements about uncertainty, bias, and limitations to help a non-scientific audience understand: (i) whether the level of uncertainty, bias, etc. is standard or unusual as compared with similar studies; and (ii) the effect of uncertainty and bias on the reliability and accuracy of the results. Scientists should also be careful not to overstate the novelty of this field—while attribution science is undergoing constant evolution, the vast majority of studies published in this field are based on well-established scientific techniques, carefully tested models, and detailed observational sets.

4. Engage with Stakeholders

Clear communication of findings is an important first step towards promoting the real-world application of attribution science; engagement is critical to successful communication, and to growing the impact of attribution research. Various researchers have already highlighted the need for dialogue between scientists and stakeholders on climate change science and attribution

654. Sophie Marjanac et al., *Acts of God, Human Influence and Litigation*, 10 NATURE GEOSCIENCE 616 (2017).

research to ensure practical relevance of this research.[655] Weaver et al. (2013) describe the importance of active-learning feedback loops—that is, processes which allow for policy-makers and other stakeholders "to communicate back to scientists any concerns, misunderstandings, relevance, or timeliness of the issues."[656] This type of co-generation of knowledge has played a central role in climate risk assessments, such as those conducted by the New York City Panel on Climate Change.[657] Some of the lessons learned from these co-generation efforts (e.g., risk management frameworks, focusing on the decision-needs of stakeholders, inclusion of social scientists and boundary spanners in the process, and working through existing, trusted networks) will help ensure attribution research is as impactful as possible. Given the expertise about impacts that resides with stakeholders, deeper stakeholder engagement can also be expected to lead to scientific advances not only in attribution science for decision-making, but also for attribution science itself, especially with respect to attribution of impacts. For example, a stakeholder engagement process with water managers encouraged attribution scientists to focus on a broader set of event metric definitions, including the duration of rain events, in order to make their research more relevant for decision-makers and sector experts.[658]

5. Link Individual Studies to Related Research To Help Flesh Out the Causal Chain from Emissions to Impact

Most attribution studies only focus on one part of the causal chain linking emissions and land use changes to impacts. To the extent that the scientists working on these studies are aware of related research, it would be helpful for them to explicitly discuss this research and explain how it ties into their own findings. For example, a study attributing specific impacts to increases in

655. *See, e.g.*, Sippel et al., *supra* note 111; Christopher P. Weaver et al., *Improving the Contribution of Climate Model Information to Decision-Making: The value and Demands of Robust Decision Frameworks*, 4 WIREs CLIMATE CHANGE 39 (2013); Hannah Parker et al., *Using a Game to Engage Stakeholders in Extreme Event Attribution Science*, 7 INT'L J. DISASTER RISK SCI. 353 (2016).

656. Sippel et al., *supra* note 111, at 225 (citing to Weaver et al., *supra* note 655).

657. *See, e.g.*, Cynthia Rosenzweig & William Solecki, New York City Panel on Climate Change, *Special Issue: Advancing Tools and Methods for Flexible Adaptation Pathways and Science Integration Policy* (The New York Academy of Sciences 2019).

658. Julie A. Vano et al., *Hydroclimatic extremes as challenges for the water management community: Lessons from Oroville Dam and Hurricane Harvey, in* BAMS 2016, *supra* note 76.

extreme heat could cite external studies demonstrating the link between increases in extreme heat and anthropogenic forcing on climate. Researchers and scientific organizations could also publish more synthesis reports linking individual studies and explaining the extent to which these studies, in aggregate, can support claims of end-to-end attribution. Where possible, it would be helpful to harmonize the scope and scale of connected studies such that the quantitative analyses conducted in one study can flow through and inform the quantitative analysis in the subsequent study, with the goal being to develop robust, quantitative findings across a larger section of the causal chain. More fundamentally, further standardization of attribution research—ranging from the selection of topics to study, to the metrics used, and the data and models brought to bear—will support cross-comparison, evaluation, and scaling up of findings across studies.

B. How Might Judges and Litigants Utilize Attribution Science in the Courtroom?

The IPCC's *Special Report on the Impacts of Global Warming of 1.5°C* highlights the necessity of achieving rapid GHG emission reductions in the immediate future.[659] With temperatures having already increased by approximately 1°C and many national governments failing to make the necessary cuts in GHG emissions, legal intervention and innovation may be necessary in order to avert catastrophic climate change. This raises the question of how judges and litigants can best utilize attribution science to help argue and decide cases, particularly those involving claims that a government or private actor should be held accountable for their contribution to or failure to regulate GHG emissions. Below, we discuss some approaches and legal innovations that could provide for a more robust assessment and application of attribution science in the courtroom.

1. Standing and Justiciability

The single greatest obstacle to the effective utilization of attribution science in the courtroom is the fact that climate cases raising complex attribution issues may be dismissed or decided

659. IPCC, SPECIAL REPORT: GLOBAL WARMING OF 1.5°C (Valerie Masson-Delmotte et al. eds., 2018).

without a trial, meaning that their scientific bases may never fully assessed and adjudicated. As discussed in Part III, the main reasons for dismissal are lack of standing, the political question doctrine, the doctrine of legislative displacement, and the doctrine of foreign affairs preemption.

With regards to standing, some courts have recognized that the questions implicated in the standing analysis are heavily fact dependent and tend to overlap with the merits of the case.[660] But other courts have denied standing based on a cursory assessment of these scientific questions, finding without trial that the causal connection between emissions and injury is too attenuated.[661] Plaintiffs should not be denied their day in court based on judicial hunches about the state of the science. Standing claims involving disputed facts should be addressed after discovery, when all issues are fully briefed and all evidence is submitted.[662] For example, the questions of what constitutes a "meaningful contribution" to GHG emissions and whether a court can provide meaningful relief should be considered factual issues to be evaluated at the merits stage.[663] The Second Circuit in *American Electric Power,* the Fifth Circuit Court in *Comer,* and the district court in *Juliana* all endorsed this approach.[664]

Some scholars have also recommended specific analytical techniques that are uniquely well-suited for assessing standing claims in cases involving climate change-related claims. For example, scholars have recommended that courts recognize that the risk of harm is itself an injury that can provide the basis for standing.[665] This would bear on how the courts interpret the

660. Juliana v. United States, 217 F. Supp. 3d 1224, 1242–1248 (D. Or. 2016). *See also* Meier, *supra* note 600, at 1248–49 (noting that the standing analysis involves many assumptions and speculation, fact-intensive inquiry, competing experts, and weighing of evidence).

661. *See, e.g.*, Native Vill. of Kivalina v. Exxon Mobil Corp., 663 F. Supp. 2d 863, 880 (N.D. Cal. 2009).

662. Causation in Environmental Law, *supra* note 591, at 2270–71; Meier, *supra* note 600, at 1265 ("the fact-specific nature of the cause in fact inquiry makes it difficult to conduct this inquiry at the threshold of litigation, and thus it is irreconcilable with the gatekeeper function of standing").

663. *See supra* Part III(C)(5).

664. *See supra* Part III(C)(1)(b).

665. Hessick, *supra* note 353, at 67–68 (arguing that all claims based on a risk of injury present an actual case or controversy that should be justiciable, no matter how small the risk, and that the "substantial risk" requirement is directly at odds with holdings that the size of the harm is irrelevant to whether a plaintiff has standing, since the risk itself is an injury);

"injury-in-fact" requirement for future harms (e.g., in cases where attribution science is primarily used to support model projections of those future harms). It may also bear on how courts interpret the causation and redressability requirements. For example, in cases involving procedural harms, the "harm" is really an increased chance of substantive harm in the future, and courts adjust their standing analysis to accommodate such harms by relaxing requirements for imminence and redressability.[666] There is some judicial precedent to support such an approach.[667]

Another approach could be to allow "fractional standing" for probabilistic injuries.[668] According to one commentator, a "fractional injury" is "one that, if manifest in one individual, would be insufficient to grant standing" but if "multiple individuals experience this injury and band together to demand relief . . . then their collective grievance would be sufficient to merit standing."[669] Fractional standing involves looking at the probability of the harm, the severity of the harm, and the number of people at risk and determining whether the aggregate harm is sufficient to grant

Lin, *supra* note 603 (involuntary risk is a harm); Sunstein, *supra* note 603 (arguing that an increased probability of harm is itself an injury-in-fact that should suffice for standing purposes in cases that involve public law claims); Claire Finkelstein, *Is Risk a Harm?* 151 U. PENN. L. REV. 963 (2003) (arguing that risk of harm is itself a harm); Meier, *supra* note 600, at 1288–91 (noting there is some precedent for this approach); Robinson, *supra* note 588, at 783 (explaining why the "basic objectives of tort law are better served if liability is based on risk of injury than if it is based on the actual occurrence of harm").

666. Burt, *supra* note 353, at 280 (citing Sierra Club v. Marsh, 872 F.2d 497, 500 (1st Cir. 1989) (Judge Breyer clarified that the underlying harm in procedural injury cases is not the "harm to procedure," but the increased risk of substantive harm (to the environment, for example) that occurs when procedures are not followed.). *See also* Hessick, *supra* note 353, at 69 (In procedural cases, "it is clear that the injury is *not* the effect of the agency action on the plaintiff" because the redress that a court could provide (making the agency follow proper procedures) will not necessarily remedy that injury. Rather "the relevant injury that is redressed in a procedural claim is the increased probability of harm.").

667. *See Duke Power Co.* 438 U.S. 59 at 73–74 (holding apprehension caused by risk of harm caused by radiation exposure was sufficient for standing); Covington v. Jefferson Cty., 358 F.3d 626, 641 (9th Cir. 2004) (holding fear that leaking hazardous material would contaminate property was sufficient for standing); Suttin v. St. Jude Med. S.C., Inc. 419 F.3d 568, 575 (6th Cir. 2005) (holding increased risk of future physical injury from the implantation of an allegedly defective device constituted injury-in-fact); Baur v. Veneman, 352 F.3d 625, 633 (2d Cir. 2003) (holding enhanced risk of disease transmission may constitute injury-in-fact); Friends of the Earth, Inc. v. Gaston Copper Recycling Corp., 204 F.3d 149, 160 (4th Cir. 2000) ("Threats or increased risk . . . constitute[] cognizable harm.").

668. Daniel E. Rauch, *Fractional Standing*, 33 YALE J. ON REG. 281 (2016).

669. *Id.* at 282.

standing.[670] The D.C. Circuit implicitly endorsed this approach in *Natural Resources Defense Council v. EPA*, discussed above.[671]

With regard to the other justiciability issues raised by courts, judges may be relying on overly broad applications of general principles, such as the separation of powers, and legal doctrines, such as political question or foreign affairs preemption, to dismiss cases involving climate claims. There are, of course, many potential reasons for judicial caution in this context. Regulation has been viewed as a more appropriate response to climate change than court intervention. It is argued that democratically elected officials and technically sophisticated bureaucrats should be making policy decisions that involve complex scientific determinations, economic tradeoffs, and difficult ethical questions. There are also concerns about opening the "floodgates" to litigation. Even with robust evidence of attribution, courts may be hesitant to adjudicate claims against governments or private actors given that the numbers of potential claimants and defendants in public trust and tort actions as well as the scope of potential court decisions and the scale of potential compensation awards are huge.

But there are important counterpoints to these arguments. First, as plaintiffs in the atmospheric trust litigation,[672] the cities' tort cases,[673] and numerous statutory cases[674] argue, these climate cases arguably fall neatly within courts' core areas of competence and well-settled legal causes of action. The scale of the problem is not a reason, in and of itself, for courts to refuse to engage in its solution. Second, there is a large gap between the level of action taken by political branches of government and the level of action needed to avert the worst impacts of climate change. Courts do have a role in policing government failures to protect people's rights, whether those be fundamental rights secured under the Constitution or a public trust inherent in our nation's and states' democracies, or substantive and procedural rights provided under statute. Finally, there is an expressive function the law can and arguably should serve. Put simply, the world will experience catastrophic climate change if we continue a business-as-usual trajectory. Judicial

670. *Id.* at 290–91.
671. *See supra* Part III(C)(1)(a)(iv).
672. *See supra* Part III(C)(3)(b).
673. *See supra* Part III(C)(5).
674. *See supra* Part III(C)(3)(a).

intervention at this time could help change our course by sending important messages to governments and private actors about responsibility for climate change, unearthing facts which will advance public discourse on this topic, and in some cases compelling action that is needed to mitigate and adapt to climate change.

2. Factual and Proximate Causation

As illustrated in Part III, some judges have expressed skepticism about whether plaintiffs pursuing climate change-related claims can establish an adequate causal nexus between the defendant's conduct and their injuries as necessary to support standing and their arguments on the merits. However, recent cases provide valuable insight into how attribution science can be used to establish both factual and proximate causation in these cases.

a. Defining Parties' Contributions to GHGs

The first step in determining whether a party is a legally relevant cause of damages associated with climate change is to define that party's contribution to increases in atmospheric GHG concentrations. Some form of quantification is necessary to establish both factual cause and proximate cause. Above, we note that there are several legal tests for determining whether a party's contribution to a larger problem is a factual cause of that problem, most of which focus on the relative size of that contribution as compared with others (e.g., whether the party made a "material contribution" to the problem).[675] Quantifying the party's GHG contribution is essential to applying these tests. As for proximate cause: the question here is whether the injury is sufficiently closely related to the allegedly wrongful conduct such that it would be reasonable to impose liability. Again, the size of the emissions contribution is relevant to this inquiry.

675. We do not mean to imply that these relative share tests are the only appropriate means of ascertaining factual causation. A court could conclude that even a small contribution to GHG emissions is a factual cause of at least some of the harmful effects of climate change. The concern, of course, is that imposing liability on small contributors would open the floodgates to litigation. But a court pursuing this approach could also rely on the proximate cause requirement to conclude that it would be unreasonable to impose liability for such a small contribution.

Defining a party's GHG contribution is not as straightforward as one might like. There may be data gaps that preclude accurate quantification. Even where adequate data exists, there are inevitably analytical questions that must be answered, such as which emissions accounting approach to use—territorial, consumption-based, or extraction-based—and how to account for historical as compared with present (and possibly even future) emissions. Lawyers and judges can turn to source attribution science to understand the relative contribution of sources under different accounting methods at different temporal scales.

Several of the cases brought to date illustrate how litigants and courts might use source attribution data to define GHG contributions:

> In *Urgenda*, the Supreme Court of the Netherlands used the Dutch national emissions inventory to define that country's GHG contribution and relied on scientific research on the global carbon budget to define its corresponding emissions reduction obligation. Specifically, the court referred to UNFCCC decisions finding that industrialized countries must reduce emissions 25–40% below 1990 levels by 2020 to limit global warming to 2°C, which was in turn based on IPCC reports outlining possible global emission reduction pathways for achieving this target.[676] The court also discussed reports which corroborated Urgenda's assertion that the Dutch government must reduce emissions by at least 25% in this timeframe, including UNEP Emissions Gap reports which found that industrialized country commitments were insufficient to limit warming to 2°C or 1.5°C, a report prepared by the PBL Netherlands Environment Assessment Agency finding that Dutch policy must be more ambitious to align it with the Paris Agreement, and data showing that Dutch per capita emissions were "relatively high" compared to other industrialized nations.[677]

The expert reports compiled in *Juliana* illustrate, among other things, how parties can disaggregate government responsibility for GHG emissions based on authorities and decisions. For example, plaintiffs provided a counterfactual scenario in which they estimated emission reductions that would have occurred if the government had pursued a certain course of action to address

676. *Urgenda* Decision (2019) at ¶¶ 7.1-7.3.6.
677. *Id.* at ¶¶ 2.2.2, 4.6, 7.3.4, 7.4.4, 7.2.9.

climate change in the past, in order to delimit the fact of government responsibility, while also presenting estimates of total emissions from energy emissions within the U.S. *and* data on potential emissions from U.S. energy exports and consumption.[678] Defendants, naturally, contested that scenario with their own experts, who argued that the U.S. government cannot be held responsible for all emissions generated within the U.S. (or by products consumed within the U.S. or fossil fuels extracted within the U.S.), and who estimated that U.S. government conduct is responsible for no more than 4–5% of total global emissions.[679] In denying the defendants' motion for summary judgement, the district court found that the pleadings submitted by both parties "make clear that plaintiffs and defendants agree that federal defendants' policies greenhouse gas emissions play a role in global climate change" even if there was a dispute as to extent of that role.[680] With regards to the quantity of emissions attributable to the U.S. government, the district court focused on the defendants' admissions regarding total U.S. emissions (e.g., defendants admitted in their answer that the U.S. is responsible for more than 25% of cumulative global CO_2 emissions from 1850 to 2012) and noted that this was much greater than the 6% of global emissions at issue in *Massachusetts*.[681] The judge did not explicitly rule on whether all cumulative U.S. emissions could be attributed to U.S. government conduct, but she did discuss the many lines of evidence demonstrating a causal connection between U.S. policies and third party emissions and found this sufficient to support causation for standing purposes at the summary judgement stage.[682]

The plaintiffs in *Juliana* also argued that territorial, consumption-based, *and* extraction-based accounting methodologies should be considered in determining the government's GHG contribution and corresponding responsibility for climate change. In their complaint, they relied primarily on estimates of cumulative

678. See *supra* Part III(C)(3)(b)(i).

679. *Id.*

680. Juliana v. United States, 339 F. Supp. 3d 1062, 1072 (D. Or. 2018).

681. *Id.* at 1092.

682. *Id.* at 1093. *See also* Juliana v. United States, 217 F. Supp. 3d 1224, 1246 (D. Or. 2016) ("DOT and EPA have jurisdiction over sectors producing sixty-four percent of United States emissions, which in turn constitute roughly fourteen percent of emissions worldwide; they allow high emissions levels by failing to set demanding standards; high emissions levels cause climate change; and climate change causes plaintiffs' injuries.").

territorial emissions to support their allegations, and then supplemented this with additional emissions attributable to U.S. consumption of fossil fuels and U.S. fossil fuel exports. As discussed in Part III, they also enlisted an expert to provide a detailed comparison of U.S. emissions under the three accounting approaches and to explain why the U.S. government should maintain consumption-based and extraction-based inventories in addition to a territorial inventory.[683] This "all-of-the-above" approach makes sense for the purposes of establishing national responsibility for climate change as a general matter or in qualitative terms. But in calculating a national and global emissions inventory and budget for the purpose of setting policy, one methodology must dominate, to avoid double and triple counting of emissions. Recognizing this, the plaintiffs in *Juliana* focused on consumption-based emissions in their requested remedy: they sought a court order compelling the U.S. government to "prepare a consumption-based inventory of U.S. CO_2 emissions" accompanied by an enforceable plan to phase out fossil fuel emissions and draw down excess atmospheric CO_2.[684] The defendants did not strongly object to a consumption-based accounting approach in their reply briefs (as their primary argument was that the U.S. government should not be held accountable for all U.S. emissions no matter what accounting approach is used), but one of their experts did express the view that transitioning to a consumption-based accounting system might be infeasible or difficult to implement.[685]

Other lawsuits rely on different emissions accounting methodologies. There is no strict requirement that different courts addressing different types of legal claims, in different jurisdictions, use the same accounting methods to impose responsibility on entities; it may well be that climate litigation results in two different parties being held responsible for the same emissions. However, while this may not strangle the litigation, it can raise concerns

683. *See* supra Part III(C)(3)(b)(i).

684. Amended Complaint, Prayer for Relief, at 94, Juliana v. United States, 217 F. Supp. 3d 1224 (D. Or. 2016) (No. 6:15-cv-01517-TC).

685. Expert Report of David G. Victor at 4, Juliana v. United States, 217 F. Supp. 3d 1224 (D. Or. 2016) (No. 6:15-cv-01517-TC) ("with respect to claims regarding the use of consumption-based accounting methods for 95 GHGs, it is my expert opinion that such methods are neither administratively, nor politically 96 straightforward to implement quickly.").

about fairness, justice, and the efficiency of the judicial system. For instance, in the lawsuits against fossil fuel companies, plaintiffs focus on extraction-based emissions, primarily relying on estimates of cumulative fossil fuel production to establish that the companies they are suing have made a "substantial contribution" to climate change.[686] In response, the defendants have argued that plaintiffs are seeking to evade precedent holding that the federal government's Clean Air Act authority displaces nuisance claims based on GHG emissions by focusing on the extraction of fossil fuels rather than consumption. The federal district court in California, in denying motions from San Francisco and Oakland to remand their cases back to state court, expressed agreement with defendants, stating that plaintiffs seek to avoid federal common law by "fixat[ing] on an earlier moment in the train of history, the earlier moment of production and sale of fossil fuels, not their combustion."[687] Relatedly, the district courts in both the Oakland case and in the New York City case dismissed the cases, in part, due to the extraterritorial implications of imposing liability for the extraction of fossil fuels and their belief that this would infringe on the foreign affairs power of the executive and legislative branches of government.[688] It remains to be seen whether other judges overseeing these lawsuits will adopt a similar perspective on the extraterritorial effects of holding fossil fuel companies liable for their contribution to climate change.

These cases also illustrate how other types of information are relevant to the analysis of proximate cause and supplement attribution data. Some of the normative considerations relevant to the proximate cause inquiry include the extent to which the company profited from the production and eventual use of fossil fuels, whether the company knew that it was producing and selling a harmful product, and whether the company engaged in unethical activities such as the obstruction of climate change science.[689]

686. *See supra* Part III(C)(5).

687. Order Denying Motion to Remand at 6, California v. BP P.L.C., (N.D. Cal. Feb. 27, 2018) (No. C 17-06011 WHA).

688. City of Oakland v. BP P.L.C., 325 F. Supp. 3d 1017 (N.D. Cal. 2018); City of New York v. BP P.L.C., 325 F. Supp. 3d 466 (S.D.N.Y. 2018).

689. The UCS publishes reports on "climate accountability" at fossil fuel companies in which it assesses companies based on these sorts of criteria. *See, e.g.*, *The Climate Accountability Scorecard,* UNION OF CONCERNED SCIENTISTS, (Oct. 23, 2018), https://www.ucsusa.org/global-warming/fight-misinformation/climate-accountability-scorecard-ranking-major-fossil-fuel-companies#.W_L31ZNKhaR [https://perma.cc/5K7X-VK9K].

Recognizing this, plaintiffs in lawsuits against fossil fuel companies have framed the allegedly tortious conduct in their complaints broadly, focusing not only on the companies' production and sale of fossil fuels, but also the fact that they knew about the potential harms of their products many years, actively concealed that information, pursued climate change disinformation campaigns, and lobbied against climate change regulations.[690] Plaintiffs in *Juliana* also touched on some similar arguments in their complaint, noting, for example, that the U.S. government "acted with deliberate indifference" when it ignored expert reports urging it to take immediate action on climate change in the early 1990s.[691]

Countries and companies may claim that they cannot be held responsible for emissions before the early 1990s because that was when the IPCC first warned the world about climate change and the UNFCCC first committed to take action to address the problem. Recognizing this, some plaintiffs, like those in *Juliana*, have focused on emissions since 1990 as the primary basis for their claims.[692] However, scholars have compiled a wealth of evidence from the 1960s, 1970s, and 1980s that put countries and companies on notice about the harmful effects of GHG emissions and the perils of climate change.[693] Plaintiffs in tort cases against fossil fuel companies rely on evidence showing that fossil fuel companies have known about the risks of their products since the 1950s to establish that they can be held responsible for historical emissions, but the plaintiffs also emphasize the point that most fossil fuel emissions have accumulated since 1980, at which time the industry already knew that their products posed a "catastrophic" threat to the global climate.[694] Given the level of industry knowledge regarding the harms of their products and the intentional concealment of these risks, some plaintiffs in these cases have also argued that companies

690. *See supra* Part III(C)(5).

691. Complaint for Declaratory and Injunctive Relief ¶ 8, Juliana v. United States, 217 F. Supp. 3d 1224 (2015) (No. 6:15-cv-01517-TC), 2015 WL 4747094.

692. First Amended Complaint, ¶¶ 141, 151, Juliana v United States, 217 F. Supp. 3d 1224 (2015) (No. 6:15-cv-01517-TC) (plaintiffs in *Juliana* also present data on historical emissions since the 1700s and cite evidence of the U.S. government knowing about the dangers of climate change as far back as 1965 to further bolster their claims).

693. Heede, *supra* note 31.

694. *See, e.g.*, Complaint for Public Nuisance ¶ 61, State of California v. BP P.L.C., No. CGC-17-561370 (filed Cal. Super. Ct., Sep. 19, 2017).

should be held strictly liable for failure to warn and for design defect.[695]

b. Establishing Causal Connections to Impacts

The cases litigated to date demonstrate that attribution science is sufficiently robust to establish causal connections between increases in GHG concentrations, global warming, and a broad range of on-the-ground impacts and harms. This is not to say *all* impacts of climate change can be definitively linked to anthropogenic influence on climate—but there is a sufficiently large subset of impacts that can be attributed with enough confidence to support litigation in one form or another. These include, for example, sea level rise, melting snowpack, increases in average temperatures and extreme heat, and ocean acidification.

The analysis in cases like *Massachusetts* and *American Electric Power* suggests that it should be relatively easy for entities like states, tribes, and cities to establish a causal connection between climate change and at least some injuries associated with it. This is not merely because of their sovereign status—it is also because these entities represent many people and assets and will experience greater harms from climate change as a result of the breadth of their interests. The same can be said for trade organizations, environmental groups with large memberships, and other non-governmental entities that represent many individuals.

Juliana illustrates some of the challenges plaintiffs may face in establishing a causal connection to individual injuries. As discussed in Part III, the plaintiffs dedicated a large portion of their briefs and expert testimony to defining that causal nexus between climate change and specific injuries, and if the case had gone to trial, this would have been one of the key factual disputes. One critical question for courts as they begin to grapple with such factual disputes is to what extent observational evidence of local impacts (e.g., loss of snowpack at ski resorts) can be used to support claims of injury in the absence of an attribution study of a matching geographic and temporal scope showing that the observed impact was caused by anthropogenic influence on climate change. The answer to this question of course depends on context, but generally

695. *See, e.g.*, Complaint, Richmond v. Chevon et al., No. C18-00055 (filed Cal. Super. Ct., Jan 22, 2018).

speaking, such observational evidence should be interpreted in light of the larger body of attribution research and assigned weight accordingly. For example, if plaintiffs submit evidence that anthropogenic influence on climate is driving snowpack declines throughout the Northern Hemisphere, then it would be reasonable to infer that the observed declines in snowpack at particular resorts in North America have also been caused by anthropogenic influence on climate even without a radically downscaled attribution study for those resorts.

We recognize that in cases like *Kivalina* and *Bellon*, courts have expressed doubt about whether it is possible to trace emissions from a particular source to specific impacts due to the nature of climate change. But if this argument was taken to its extreme, then no one could be held responsible for climate change. From a technical standpoint, given that GHG emissions disperse throughout the atmosphere and have a relatively uniform effect, it would be more accurate to say that *all* emissions can be traced to impacts. And as discussed below, the emissions contribution of a party can be used as a proxy for its contribution to an impact.

Litigants and courts should be aware of both the strengths and limitations of attribution science when framing and analyzing arguments. Plaintiffs may prove most successful where they base their claims on impacts which can be attributed to anthropogenic climate change with high confidence, such as sea level rise, melting snowpack, increases in average temperatures and extreme heat, and ocean acidification. Plaintiffs may also prove most successful where they rely on expert reports and peer-reviewed attribution studies and avoid making causal inferences even for those impacts for which there is a very robust connection to anthropogenic climate change. Judges, meanwhile, should be mindful of the fact that there are different levels of confidence for different impacts, pay close attention to the evidence submitted, and should not dismiss claims based on generalized conclusions about the uncertainty of the science. Judges should also be aware that, when translating global or regional impacts to specific injuries, it may be necessary to accept causal inferences, as with the snowpack example presented above.

3. Proving and Defending against Obligations and Redressability

Few jurisdictions have addressed in even a preliminary way critical questions regarding the scope and extent of private and governmental obligations to address climate change. As discussed above, there is some precedent affirming national obligations in other jurisdictions (e.g., *Urgenda*), but no U.S. court has yet found that the federal government is bound to any particular level of climate ambition. Recall that *Massachusetts* held that EPA had failed to justify its decision not to issue GHG regulations for motor vehicles; it did not mandate that EPA actually issue the regulations, far less that it issue regulations achieving one or another standard.[696]

Urgenda illustrates how attribution science can be used to help establish national emission budgets. Source attribution data is constantly improving and estimates of carbon budgets are constantly being revised in light of new emissions data, so it will be important for litigants and courts to rely on the most recent data in framing carbon budgets.[697] The understanding that carbon budgets are a moving target could also factor into the remedy prescribed by courts in cases like *Urgenda*. For example, rather than mandating a government achieve a specific target on a specific date, a court could require the government to establish and periodically update its target based on the best available science. Attribution science could also be used to define more specific obligations for national governments, such as obligations pertaining to fossil fuel development and subsidies (source attribution data on extraction emissions would be particularly relevant here). For example, in the Colombian case holding that the government violated fundamental rights by failing to address the risks posed by climate change, the court relied on research showing the contribution of deforestation to climate change in determining that the Colombian government had an obligation to protect, conserve, maintain, and restore the portion of the Amazon forest located within Colombia.[698] In particular, the court cited: (i) estimates from Colombia's Institute of Hydrology, Meteorology,

696. *See supra* Part III(C)(3)(a)(i).
697. *See* discussion *supra* Part II(B)(4).
698. Corte Suprema de Justicia [C.S.J.] [Supreme Court], April 5, 2018, STC4360, No. 11001-22-03-000-2018-00319-01 (Colom.), http://climatecasechart.com/non-us-case/future-generation-v-ministry-environment-others/ [https://perma.cc/53WU-NLJK].

and Environmental Studies (IDEAM) finding that the increase in GHG emissions resulting from deforestation in the Amazon forest would generate an increase in Colombia's temperature by 0.7–1.1°C between 2011 and 2040, by 1.4–1.7°C between 2041 and 2080, and by as much as 2.7°C between 2017 and 2100; (ii) qualitative findings from IDEAM that the GHG increase from deforestation would also result in more precipitation in some areas and less precipitation in other areas, potentially exacerbating problems such and pollutant loadings (during wet periods) and drought; and (iii) a government report finding that reducing deforestation to zero by 2020 would ensure that "44 megatons of greenhouse gases would not enter the atmosphere."[699]

In establishing obligations for private actors, one critical question will be how to allocate liability and damages among multiple companies. The plaintiffs in *RWE* have already provided the courts with one possible approach: they are seeking damages that are proportionate to the company's individual GHG contribution (thus pursuing several liability). The municipal plaintiffs suing fossil fuel companies have pursued a slightly different approach, seeking to hold these companies jointly and severally liable for their aggregate contribution climate change. Judges may view joint and several liability as a slippery slope in this context, given that there are so many potential defendants who could be joined in these cases. Another alternative would be to hold upstream manufacturers liable for the production and sale of harmful products under a market share theory of liability (e.g., apportioning liability among fossil fuel companies based on their share of fossil fuel sales).[700]

Arguably, imposing several liability based on the party's proportionate contribution to GHG increases is the approach which best reflects the party's "true" contribution to climate change impacts. A market-share approach would also accomplish this if

699. *Id.* ¶¶ 11.1, 11.3.

700. For more on this topic, *see* Grimm, *supra* note 553, at 216 ("Market share liability has often been found appropriate only where products are sufficiently interchangeable such that it is either impossible or overwhelmingly burdensome to isolate individual causation among defendants."); Andrew B. Nace, Note, *Market Share Liability: A Current Assessment of a Decade-Old Doctrine*, 44 VAND. L. REV. 395, 396–97 (1991); Samantha Lawson, *The Conundrum of Climate Change Causation: Using Market Share Liability to Satisfy the Identification Requirement in* Native Village of Kivalina v. ExxonMobil Co., 22 FORDHAM ENVTL L. REV. 433 (2010); Daniel A. Farber, *Basic Compensation for Victims of Climate Change*, 155 U. PA. L. REV. 1605, 1640–55 (2007). *But see* Kysar, *supra* note 555, at 37 (critiquing the market share liability approach and recommending that several liability is the appropriate form of recovery).

the "market share" were defined as the share of GHG emissions, (in which case this would be identical to the several liability approach)—but if the "market share" is the share of fossil fuels produced or electricity generated, then this approach might overestimate the actual contribution to the injury (insofar as other GHG sources, such as agriculture and land use change, would not be accounted for in the contribution determination). Imposing joint and several liability might also result in an overestimation of a party's contribution to the injury. However, there may be compelling reasons to impose joint and several liability in certain contexts—for example, in the municipal lawsuits against fossil fuel companies, the plaintiffs note that the companies colluded in climate change misinformation campaigns, and that each company was "the agent, servant, partner, aider and abettor, co-conspirator, and/or joint venture" of the other defendants to justify their request for joint and several liability.[701]

V. CONCLUSION

In this Article, we summarize the state of the art in climate change detection and attribution science; describe how that science is being used in policy, planning, and litigation; and discuss further directions in the law and science of climate change attribution. We focus, in particular, on the use of attribution science in the courtroom. Attribution science has always been a key component of climate change litigation. But, the recent waves of cases brought against national and subnational governments, seeking increased mitigation ambition, and against fossil fuel and energy companies, seeking compensation or abatement funds for the costs of adaptation, have made the relationship between the science and law of climate change attribution all the more salient.

The political sphere in the United States continues to be clouded with false debates over the validity of climate science. Things are far clearer in the courtroom, where to our knowledge no judge has questioned the scientific basis for the global community's shared understanding of the causes and effects of climate change. But there are significant scientific issues that remain to be clarified, for

701. *See, e.g.*, Complaint ¶ 40, Imperial Beach v. Chevon et al., No. C17-01227 (filed Cal. Super. Ct., July 17, 2017); Complaint ¶ 44, Richmond v. Chevon et al., No. C18-00055 (filed Cal. Super. Ct., Jan 22, 2018).

law and policy purposes, and it may well be that litigation provides the forum for achieving that clarity.

ANEXO 4

State of the Climate in Latin America and the Caribbean

2021

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1295

Cover photo: Agua y recursos Naturales en América Latina y el Caribe (Credits: FAO/Max Valencia).

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Contents

Key messages

The warming trend continued in 2021 in Latin America and the Caribbean. The average rate at which temperatures increased was around 0.2 °C per decade between 1991 and 2021, compared to 0.1 °C per decade between 1961 and 1990.

In 2021 the temperature was above the 1981–2010 average in all subregions, with the highest anomaly value of +0.59 (±0.1 °C) in the Mexico and Central America domain, corresponding to +0.97 (±0.1 °C) above the WMO 1961–1990 reference period for climate change.

Glaciers in the tropical Andes have lost at least 30% of their area since the 1980s, with a negative mass balance trend of –0.97 m water equivalent per year during the 1990–2020 monitoring period. Glacier retreat and the corresponding ice-mass loss has increased the risk of water scarcity for the Andean population and ecosystems.

Sea levels in the region continued to rise in 2021 at a faster rate than globally, notably along the Atlantic coast of South America south of the equator, and the subtropical North Atlantic and Gulf of Mexico. Sea-level rise threatens a large proportion of the population, which is concentrated in coastal areas – by contaminating freshwater aquifers, eroding shorelines, inundating low-lying areas and increasing the risks of storm surges.

The "Central Chile Mega-drought" continued in 2021, at 13 years to date constituting the longest in one thousand years, exacerbating a drying trend and putting Chile at the forefront of the region's water crisis. A multi-year drought in the Paraná–La Plata Basin, the worst since 1944, affected central-southern Brazil, parts of Paraguay and the Plurinational State of Bolivia.

In the Paraná–La Plata Basin, drought-induced damage to agriculture reduced crop production, including of soybeans and corn, affecting global crop markets. In South America overall, drought conditions led to a decline of 2.6% in the 2020–2021 cereal harvest compared with the previous season.

The 2021 Atlantic hurricane season was the third-most active Atlantic hurricane season on record with 21 named storms, including seven hurricanes, and was the sixth consecutive above-normal Atlantic hurricane season.

Extreme rainfall (with record values in many places), floods and landslides induced substantial losses in 2021, leading to hundreds of lives lost, tens of thousands of homes destroyed or damaged and hundreds of thousands of people displaced. Floods and landslides in the Brazilian states of Bahia and Minas Gerais led to an estimated loss of US$ 3.1 billion.

Deforestation in the Brazilian Amazon rainforest doubled compared to the 2009–2018 average, reaching its highest level since 2009. Compared to 2020, 22% more forest area was lost in 2021.

A total of 7.7 million people, in Guatemala, El Salvador and Nicaragua experienced high levels of food insecurity in 2021, with contributing factors including continuing impacts from Hurricanes *Eta* and *Iota* in late 2020 and COVID-19 pandemic economic impacts.

South America is among the regions with the greatest documented need for strengthening of early warning systems. Multi-hazard early warning systems (MHEWS) are essential tools for effective adaptation in areas at risk from weather, water and climate extremes.

Foreword

After the successful publication of the first WMO report on the State of the Climate in Latin America and the Caribbean (LAC) last year, I am pleased to see the timely publication of this second edition. This second report has involved National Meteorological and Hydrological Services (NMHSs), WMO Regional Climate Centres (RCCs), and several research institutions, as well as an increased number of contributing United Nations agencies, and international and regional organizations.

The report shows that hydrometeorological hazards, including droughts, heatwaves, tropical cyclones and floods, have unfortunately led to the loss of hundreds of lives, caused severe damage to crop production and infrastructure, and induced population displacement.

Increasing sea-level rise and ocean warming are expected to continue to affect coastal livelihoods, tourism, health, food, energy and water security, particularly on small islands and in Central American countries. For many Andean cities, melting glaciers represent the loss of a significant source of fresh water currently used for domestic use, irrigation and hydroelectric power. In South America, the continued degradation of the Amazon rainforest is still being highlighted as a major concern, not only for the region but also for the global climate, considering the role of the forest in the carbon cycle.

In addition to describing climate trends, extreme events and associated impacts, the report identifies knowledge gaps and areas for improvement for better supporting climate action in the LAC region. Despite the continuous efforts in strengthening multi-hazard early warning systems, the report points out clearly that there are still significant gaps to be addressed to strengthen these systems to reduce adverse impacts of hydrometeorological hazards in the region.

The information in this report is built on observing systems coordinated by WMO and its partner organizations. The WMO Integrated Global Observing System (WIGOS) provides basic weather and climate information, and the Global Climate Observing System (GCOS) defines a broader set of Essential Climate Variables (ECVs) that are needed to monitor the global climate, and support mitigation and adaptation.

While the evidence for climate change is unequivocal, the most recent reports of the Intergovernmental Panel on Climate Change (IPCC) show that there remain significant gaps in the observation in developing countries. The WMO Global Basic Observing Network (GBON) and the Systematic Observations Financing Facility that supports it will provide critically needed observations for numerical weather prediction and will help substantially strengthen climate monitoring.

I take this opportunity to congratulate the experts from the region and worldwide for leading the scientific coordination and authorship of this report and thank WMO Members and sister United Nations agencies for their continuous commitment to supporting this publication, through providing input and contributing to the report review process.

(Prof. Petteri Taalas)
Secretary-General

Preface

The Latin America and the Caribbean region is home to some of the widest biodiversity on the planet. From Caribbean marine and coastal oases to the Amazon rainforest and down to the southern-most reaches of Patagonia, the region is filled with natural wealth.

However, the increasing impact of climate change and climate variability, compounded by the effects of the COVID-19 pandemic have not only undermined the productivity of ecological systems in the region, but have also stalled decades of advancement against poverty, inequality and food insecurity in the region. Rising sea levels and warming oceans are threatening the health of marine and coastal ecosystems. Drought, landslides, saltwater intrusion, extreme heat and human-induced land use changes have contributed to deforestation rates reaching their highest levels in 15 years. This trend is impacting terrestrial ecosystems, near-shore urban developments and other human settlements, as well as sustainable livelihoods, soil productivity and tourism opportunities. In the meantime, melting glaciers, mega-droughts, extreme rainfall and flooding are putting food production and water security at risk for both rural and urban populations across the region. The devastation caused by the frequency and ferocity of extreme hydro-climatic events in the Caribbean is especially overwhelming for the small island, low-lying and coastal States of the subregion.

Addressing such interrelated challenges and multidimensional vulnerabilities will require a well-articulated, prioritized and integrated effort. The coral reef restoration projects ongoing in the Caribbean and Pacific are good examples of this. They seek to re-establish self-sustaining, functioning reef ecosystems affected by ocean warming and acidification, among other stressors, while demonstrating the advantages of effective collaboration between academia and practitioners for collective problem-solving.

Strengthening partnerships and alliances with diverse stakeholders can also create long-term and regional and national solutions. For example, the Climate Action Platform for Agriculture in Latin America and the Caribbean (PLACA), launched at the twenty-fifth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP25), is as a voluntary regional collaboration mechanism on climate action in agriculture. PLACA promotes collaboration among LAC countries to implement mitigation and adaptation measures that can support regional and national strategies regarding climate change impacts and climate variability in the agricultural sector. The platform brings together representatives from twelve ministries of agriculture in the region, so far, along with six partner organizations and several United Nations organizations, including the Economic Commission for Latin America and the Caribbean (ECLAC), the Food and Agricultural Organization of the United Nations (FAO) and WMO.

The report on the State of the Climate in Latin America and the Caribbean, the second of its kind, is a critical source of science-based information and data. Informed by science, this report serves to support climate-related policy design and decision-making. ECLAC will continue to play an active role through the provision of policy support, capacity building, and the improved dissemination of weather, climate-change and climate variability data and information services. This dedicated support will serve to better foster decisive action and continue promoting more effective climate change mitigation and adaptation policies with all stakeholders across Latin America and the Caribbean.

Mario Cimoli
ECLAC Acting Executive Secretary

Global climate context

The global annual mean temperature in 2021 was 1.11 ± 0.13 °C above the 1850–1900 pre-industrial average – less warm than in some recent years owing to cooling La Niña conditions at the start and end of the year. The year 2021 was between the fifth and seventh warmest year on record according to six data sets (Figure 1).[1] The past seven years, 2015 to 2021, were the seven warmest years on record. The year 2016, which started during a strong El Niño, remains the warmest year on record in most data sets.

Atmospheric concentrations of the three major greenhouse gases reached new record highs in 2020, with levels of carbon dioxide (CO_2) at 413.2 ± 0.2 parts per million (ppm), methane (CH_4) at 1 889 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 333.2 ± 0.1 ppb – respectively 149%, 262% and 123% of pre-industrial (before 1750) levels. Real-time data from specific locations, including Mauna Loa (Hawaii) and Cape Grim (Tasmania) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2021. Increasing greenhouse gas concentrations lead to an accumulation of heat in the climate system, much of which is stored in the ocean.

Over the past two decades, the ocean warming rate strongly increased, and the ocean heat content in 2021 was the highest on record. Ocean warming and accelerated loss of ice mass from the ice sheets contributed to the rise of the global mean sea level by 4.5 mm per year between 2013 and 2021, reaching a new record high in 2021. The ocean absorbs about 23% of annual anthropogenic emissions of CO_2 into the atmosphere, thereby helping to alleviate overall warming; however, CO_2 reacts with seawater and lowers its pH. This process, known as ocean acidification, affects many organisms and ecosystem services, and threatens food security by endangering fisheries and aquaculture.[2,3]

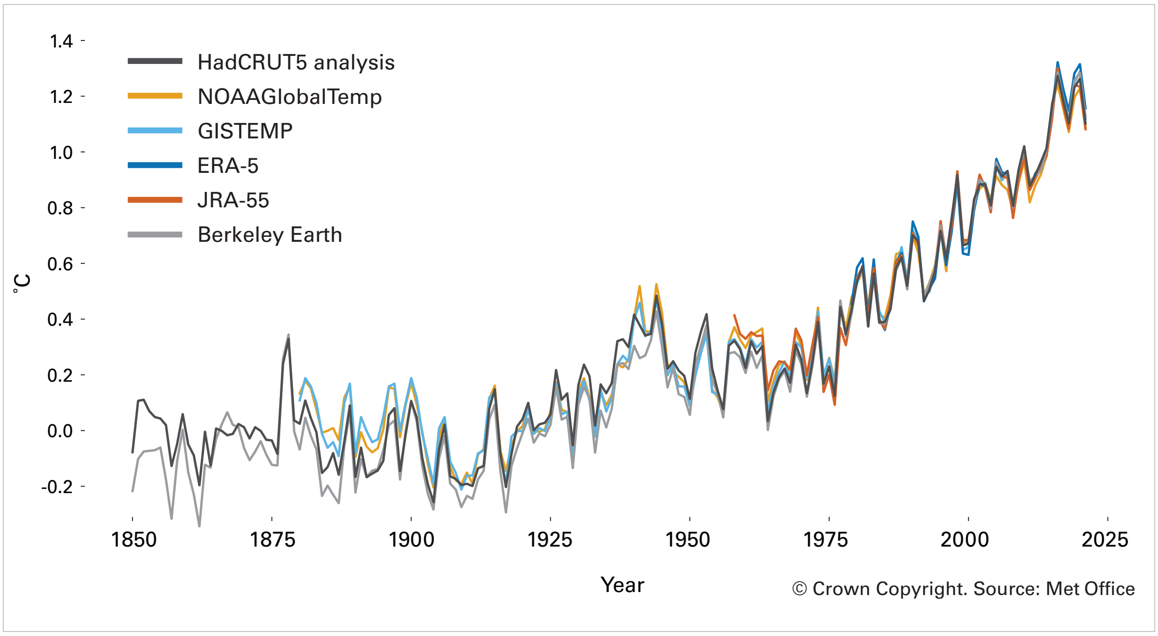


Figure 1. Global annual mean temperature difference from pre-industrial conditions (1850–1900) for six global temperature data sets: HadCRUT5, NOAAGlobalTemp, GISTEMP, Berkeley Earth, ERA5 and JRA55. *Source:* Met Office, United Kingdom of Great Britain and Northern Ireland.

Regional climate

The following sections analyse key indicators of the state of the Latin America and Caribbean regional climate. One important such indicator, temperature, is described in terms of anomalies, or departures from a reference period. For global mean temperature, the reference period used in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC),[4] 1850–1900, is used for calculating anomalies in relation to pre-industrial levels. The pre-industrial period cannot be used as a baseline for calculating regional anomalies, however, due to insufficient data for calculating region-specific averages prior to 1900. Regional temperature anomalies are therefore expressed relative to the 30-year 1961–1990 reference period, which is the fixed period recommended by WMO as a consistent and stable reference for assessing long-term climate change, especially for temperature. The 1981–2010 climatological standard normal period is also used, for computing anomalies in temperature and other indicators with reference to more recent climate average conditions. Exceptions to the use of these baseline periods for the calculation of anomalies, where they occur, are explicitly noted.

TEMPERATURE

Despite being cooler than recent years due to the influence of a moderate La Niña, 2021 was, according to the six data sets,[5] between the sixth and the tenth warmest year in Mexico/Central America, between the seventh and the seventeenth warmest in the Caribbean and between the sixth and the sixteenth warmest in South America.

The warming trend continued in 2021 in Latin America and the Caribbean. The average rate of temperature increase in the region was around 0.2 °C per decade between 1991 and 2021, compared to 0.1 °C per decade between 1961 and 1990 (Figure 2). The warming rate in Mexico and Central America, 0.27 [0.22–0.30] °C per decade, suggests that this subregion likely warmed faster in 1991–2021 than the Caribbean and South America, which warmed at 0.24 [0.19–0.30] °C and 0.23 [0.21–0.26] °C per decade, respectively (Figure 2).

Observed temperature anomaly relative to 1961–1990

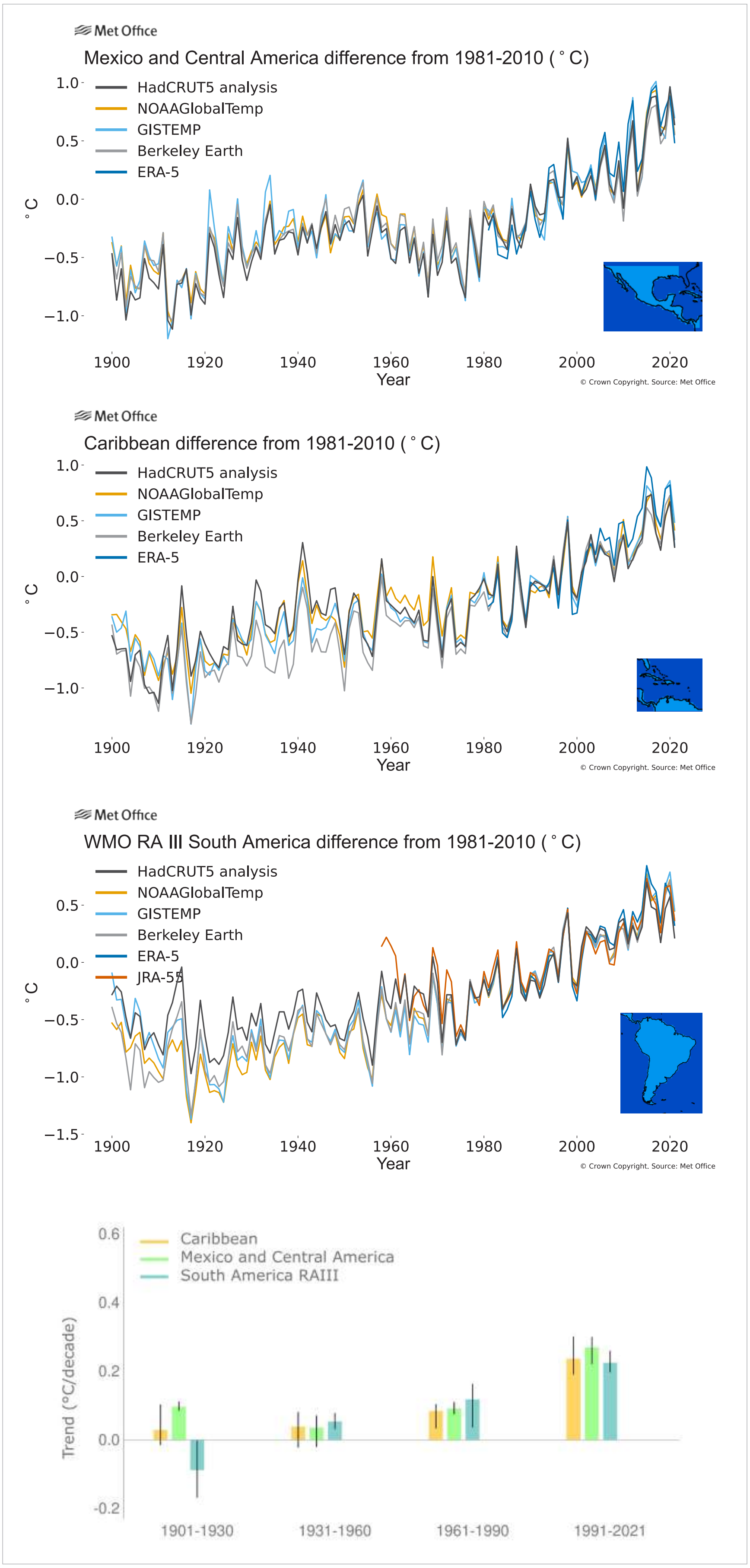
Average temperatures in 2021 were 0.97 [0.87–1.08] °C,[6] 0.68 [0.56–0.79] °C and 0.69 [0.50-0.83] °C above the 1961–1990 average in Mexico and Central America, the Caribbean and South America, respectively.

Observed temperature anomaly relative to a recent climatological standard normal

The use of 1981–2010 for computing temperature anomalies provides a more recent benchmark for operational climate monitoring and applications in various sectors, such as adaptation planning and decision-making. Average temperatures were 0.59 [0.49–0.70] °C, 0.35 [0.26–0.48] °C and 0.36 [0.21–0.45] °C above the 1981–2010 average in Mexico and Central America, the Caribbean and South America, respectively.

In most land areas of the region, annual temperatures were warmer than the 1981–2010 average. Anomalies of +1 °C to +3 °C were recorded in central Mexico, the Yucatán peninsula, Guatemala, Honduras and El Salvador (Figure 3a, 3b), and +0.5 °C in Nicaragua, while some relative cooling was recorded in Costa Rica and Panama. In the Caribbean, positive temperature anomalies were recorded in the Dominican Republic, Jamaica and the small Caribbean islands (Figure 3c). In South America, above-normal temperature anomalies prevailed over the entire continent, with +1 °C to +2 °C in north-east Brazil, Colombia, central Brazil, central Chile, and central and southern Argentina (Figure 3d). Anomalies of +0.5 °C were also recorded in central Amazonia, northern Argentina, Paraguay and Peru. Negative temperature anomalies were observed in the extreme north of the Bolivarian Republic of Venezuela, Guyana, north-east of Chile, west of Uruguay and extreme north of Brazil.

Figure 2. Average temperature anomalies (relative to 1981–2010) for (a) Mexico and Central America, (b) the Caribbean and (c) South America. Data are from six different data sets: HadCRUT5, NOAAGlobalTemp, GISTEMP, Berkeley Earth, ERA5 and JRA55. Panels (a) and (b) do not include the JRA55 data set. Panel (d): trends for four 30-year periods as indicated on the x-axis. Coloured bars are the average trend calculated over each period for each of six data sets: HadCRUT5, NOAAGlobalTemp, GISTEMP, Berkeley Earth, ERA5 and JRA55. The black vertical line indicates the range of the six estimates. *Source:* Met Office, United Kingdom.



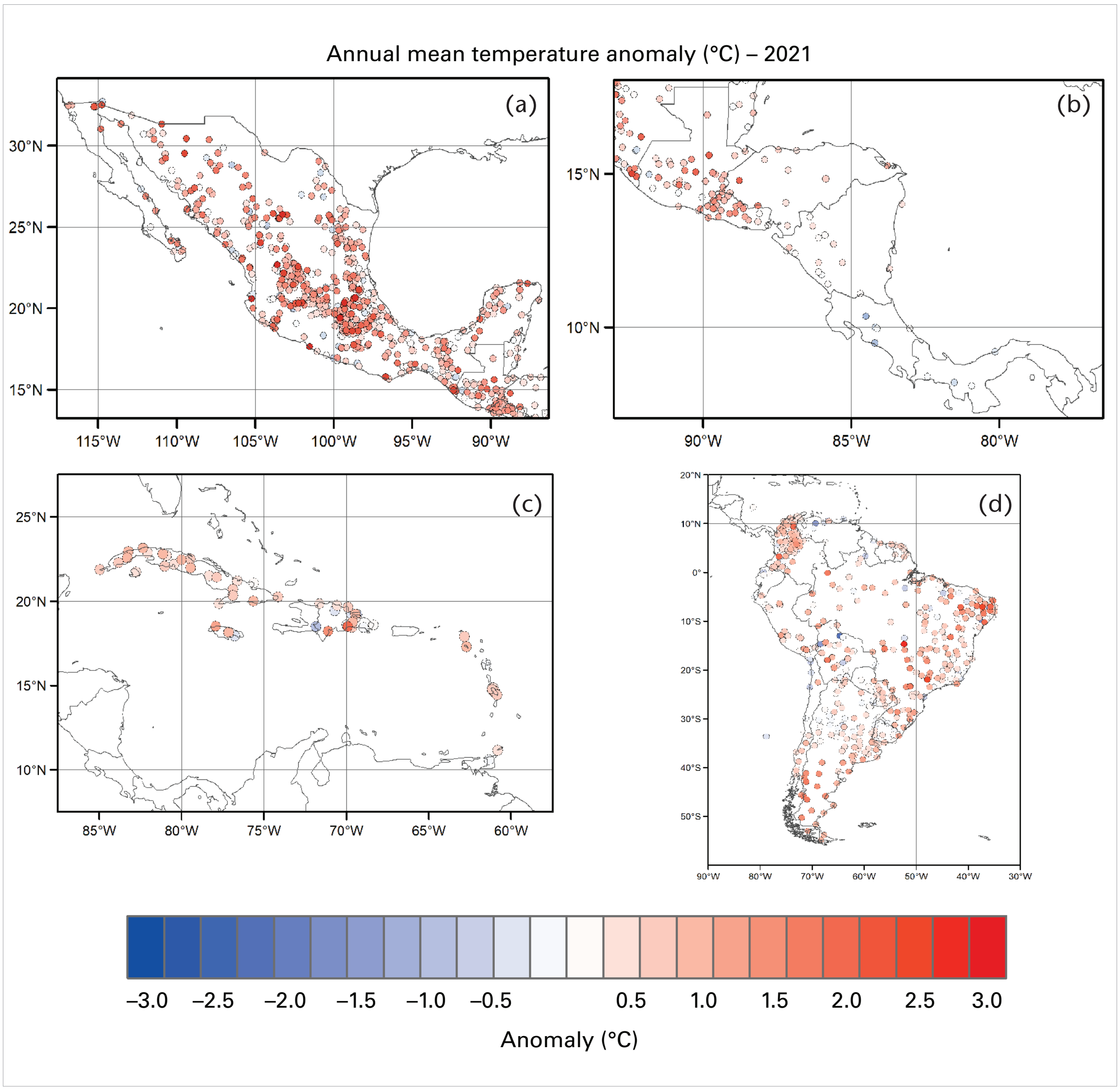


Figure 3. Air temperature (2 m) anomalies for 2021 (relative to 1981–2010) for (a) Mexico, (b) Central America, (c) the Caribbean and (d) South America, in °C. *Source:* International Research Centre on El Niño (CIIFEN), from National Meteorological and Hydrological Services data.

PRECIPITATION

In this section the 1981–2010 climatological standard normal is used for computing 2021 rainfall anomalies, expressed as a percentage above or below normal.

Rainfall in central Mexico was around 40%–60% above normal, while north-west Mexico and Baja California recorded rainfall around 20% below normal (Figure 4a). In the north Atlantic coast and over the Yucatán peninsula, Guatemala and El Salvador, rainfall anomalies ranged from 50% below normal to 20% above normal (Figure 4b). Below-normal rainfall was recorded in Belize and Nicaragua, while Costa Rica and much of Panama recorded above-normal rainfall.

In the Caribbean region, below-normal rainfall was recorded in Cuba, the Dominican Republic and the small Caribbean islands (Figure 4c). For example, in much of Guadeloupe, annual rainfall was 10%–50% below normal.

In South America (Figure 4d), rainfall anomalies of between 20% and 60% below normal were recorded over the central and southern regions of Chile, and 30% to 50% below normal over the south-western Andes of Peru. Below-normal rainfall was dominant over the Paraná–La Plata Basin in south-eastern Brazil, northern Argentina, Paraguay and Uruguay, suggesting a late onset and weak South American Monsoon. Below-normal rainfall conditions dominated the semiarid region of north-east Brazil and the Caribbean coast of the Bolivarian Republic of Venezuela.

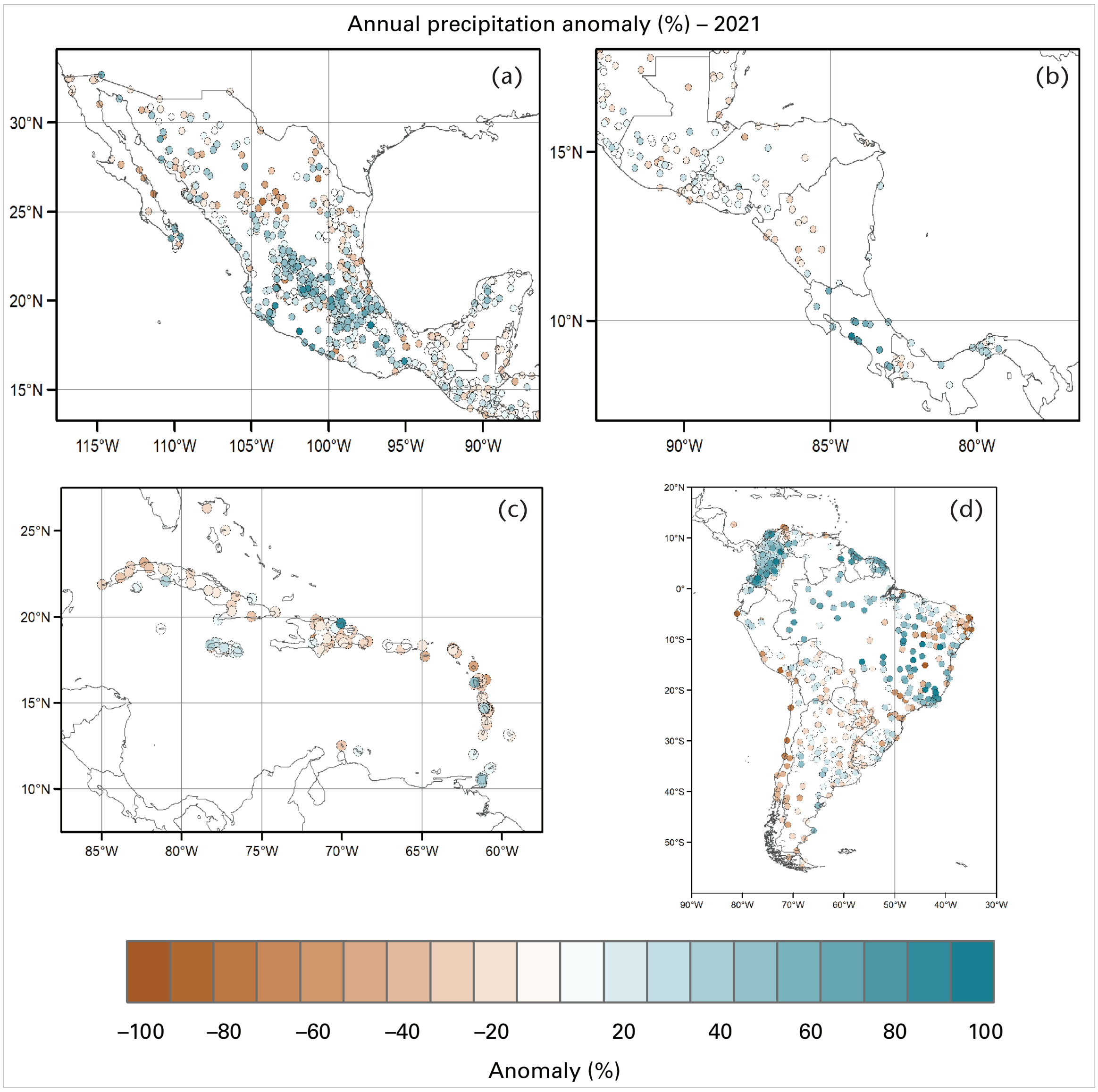


Figure 4. Rainfall anomalies for 2021 (% with respect to the 1981–2010 reference period) in (a) Mexico, (b) Central America, (c) the Caribbean and (d) South America. *Source:* CIIFEN, from National Meteorological and Hydrological Services data.

Conversely, the western side of Colombia, central Amazonia, French Guyana, Suriname and Guyana recorded above-normal rainfall for the year. Some of the observed rainfall patterns were in line with the typical rainfall patterns associated with La Niña conditions (verified during most of 2021, see Sea-surface temperature).

GLACIERS

Assessment of the recent evolution of the ice masses in the Andes region[7] is based on the mass balance time series from the World Glacier Monitoring Service. In the tropics, glacier mass balance has a negative trend of around –0.97 m water equivalent (w.e.) per year during the monitoring period (1990–2020) (Figure 5a). Remote sensing observations show that surface area reductions in the tropics have fluctuated from 25% to 50% since the 1950s, with significant ice-mass loss occurring since the late 1970s.[8] Further south, in the Andes of Chile and Argentina, glaciers have also been retreating for decades, with a differential rate of around –0.72 m w.e. per year for the 2004–2021 period in the dry Andes and –0.56 m w.e. per year from 1976 to 2021 in the southern Andes (Figure 5b and Figure 5c, respectively). These observed glacier mass loss rates are among the highest regional mass loss rates globally.[9]

On average, the tropical Andes glaciers have lost at least 30% of their area since the 1980s.[10] The current glacier area has shrunk rapidly since the 1970s in Peru (losses of 54%, 56% and 64% for the Cordilleras Vilcanota, Vilcabamba and Urubamba, respectively), with low-lying glaciers receding the most across all regions.[11] The corresponding ice-mass loss has increased the risk of water scarcity for the Andean population and ecosystems.[12]

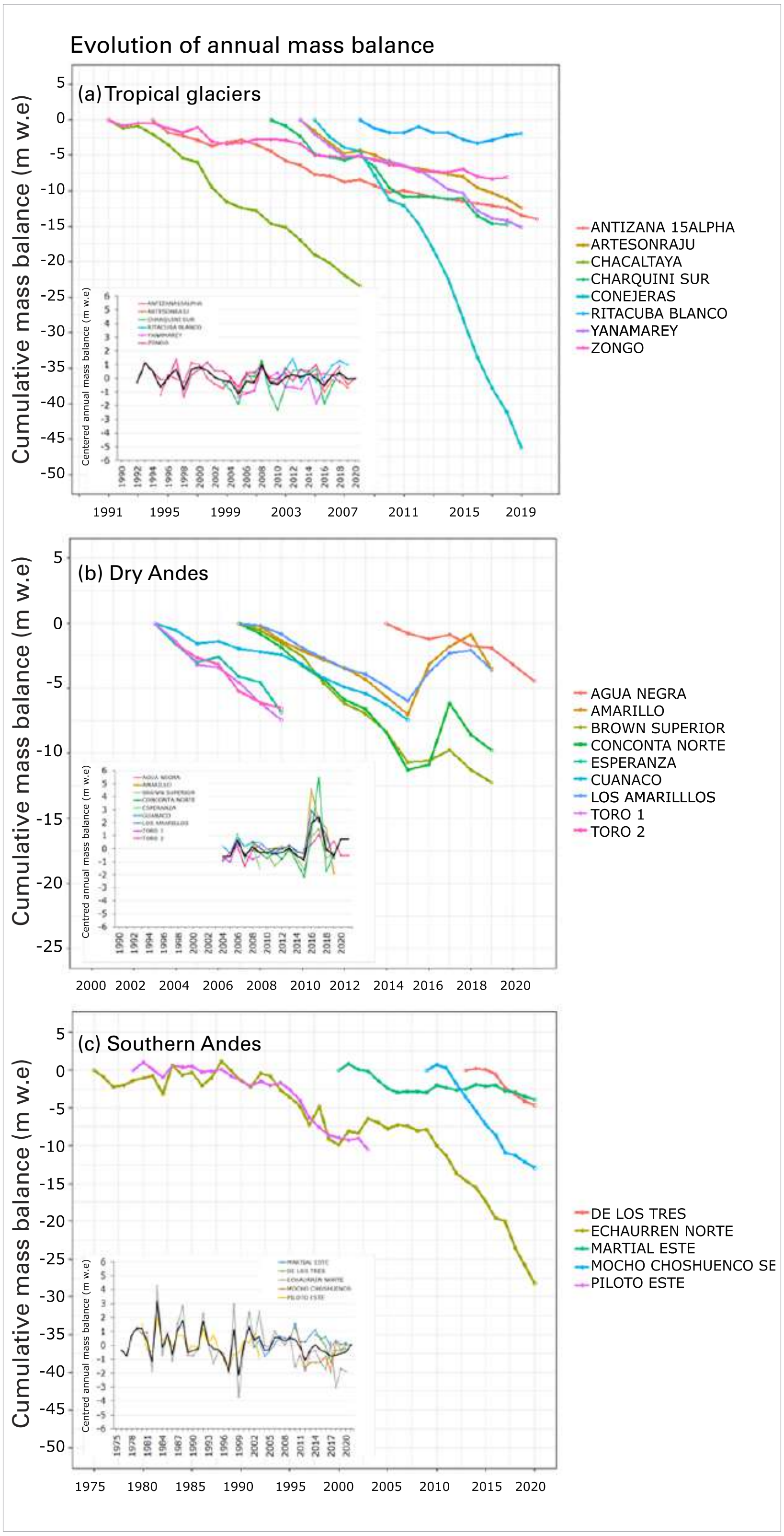


Figure 5. Cumulative mass balance of 22 monitored glaciers showing the evolution of the Andean ice masses in the three main regions: (a) tropics, 1990–2020; (b) dry Andes, 2004–2021 and (c) southern Andes, 1976–2021. The inset in each panel shows the centred mass balance of the time series; the average centred balance is shown by a black line. *Source:* data from World Glacier Monitoring Service (WGMS).

SEA-SURFACE TEMPERATURE

Sea-surface temperature (SST) is the mean temperature in the top few metres of the ocean.[13] It is a vital component of the climate system as it exerts a major influence on the exchanges of energy, momentum and moisture between the ocean and atmosphere. The SST largely controls the atmospheric response to the ocean on both weather and climate timescales. Spatial patterns in SST reveal the structure of the underlying ocean dynamics, such as ocean fronts, eddies, coastal upwelling and exchanges between the coastal shelf and open ocean.[14] In a warmer world, warmer SSTs lead to more frequent marine heatwaves, coral bleaching, and damage to reefs and related fisheries.[15,16]

Central and eastern Tropical Pacific SST conditions are especially crucial for identifying the onset of El Niño and La Niña and their influence on climate patterns and extremes, both worldwide and in particular in the LAC region. El Niño and La Niña together with the Southern Oscillation, defined as the atmospheric pressure difference between Tahiti and Darwin, comprise the El Niño Southern Oscillation (ENSO). La Niña conditions emerged in mid-2020 and peaked in the October–December period at moderate strength. La Niña weakened through the first half of 2021, reaching an ENSO-neutral state in May, according to both oceanic and atmospheric indicators. However, SSTs cooled after mid-year, reaching La Niña thresholds once again by the July–September period. By the October–December period, average SSTs once again reached moderate strength, at 1.0 °C below normal.[17]

La Niña typically leads to increased rainfall in northern Brazil, Colombia and other northern parts of South America and is associated with reduced rainfall in Uruguay and parts of Argentina. Drier-than-normal conditions are generally observed along coastal Ecuador and in north-western Peru.[18,19] Rainfall anomalies in 2021 in South America were comparable to these typical La Niña rainfall patterns (see Precipitation).

The tropical North Atlantic and adjacent ocean areas were cooler than normal from February to August 2021, and warmer from September to December, reaching 0.5 °C above average (1981–2010) in November 2021. The SST anomaly in the Caribbean Sea was +0.69 °C above the average, lower than the 2020 value of +0.98 °C. In the Gulf of Mexico, SST anomalies reached +0.43 °C, also lower than the 2020 values of +0.78 °C (Figure 6).

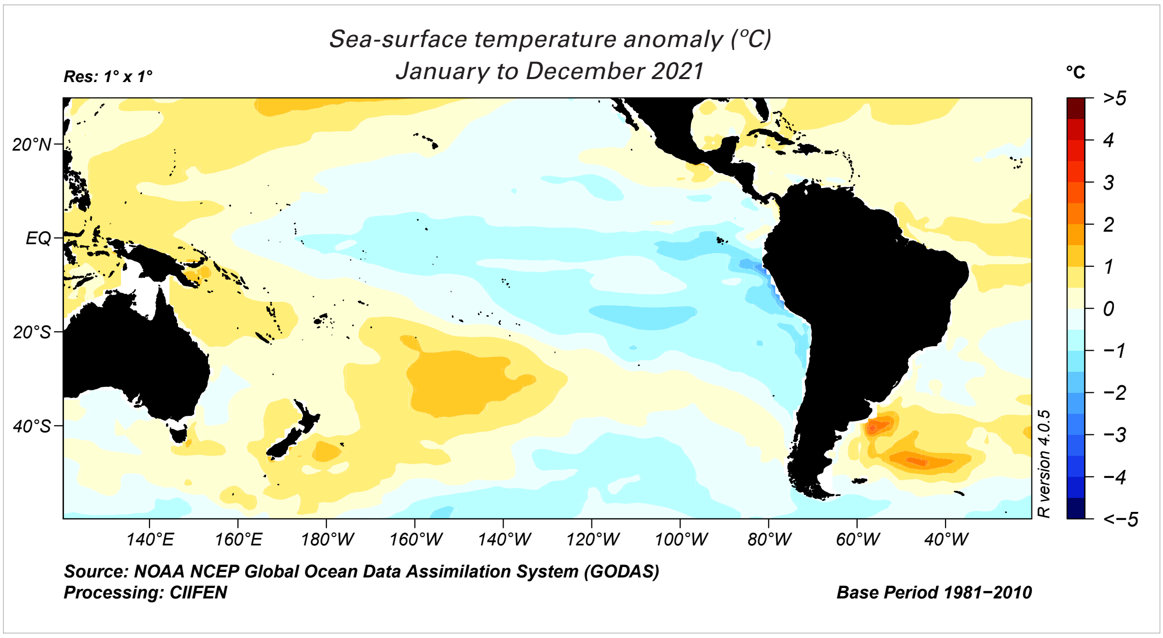


Figure 6. Annual SST anomalies in 2021. Reference period is 1981–2010. *Source:* CIIFEN.

SEA LEVEL

The abundance of heat-trapping greenhouse gases in the atmosphere once again reached a new record in 2020, with the annual rate of increase above the 2011–2020 average, a trend that continued in 2021.[20] Most of the excess energy that accumulates in the Earth system due to increasing concentrations of greenhouse gases is taken up by the ocean. The added energy warms the ocean, and the consequent thermal expansion of the water leads to sea-level rise, to which is added melting land ice.

Compared to global mean sea level, over the last three decades relative sea level has increased at a higher rate than global mean in the South Atlantic and the subtropical North Atlantic, and at a lower rate in the East Pacific.[21] Sea-level rise threatens the large portion of the Latin American and Caribbean population which lives in coastal areas – by contaminating freshwater aquifers, eroding shorelines, inundating low-lying areas and increasing the risks of storm surges.[22] Figure 7 shows sea-level trends in two LAC subregions – South America (panel a) and Mexico, Central America and the Caribbean (panel b) – each of which is divided into three domains.[23]

Based on high-precision satellite altimetry data covering the period 1993 to 2022, the rates of sea-level change on the Atlantic side of South America are higher than on the Pacific side (Figure 7a). In the South America Pacific region, rate of change is 2.45 ± 0.1 mm per year, less than the global average, 3.33 ± 0.4 mm per year. Along the Atlantic coast of South America, south of the equator, the rate of change is 3.52 ± 0.0 mm per year, and along the tropical North Atlantic coast of South America it is 3.28 ± 0.1 mm per year. Comparable rates are also recorded in the subtropical North Atlantic, around the Caribbean and the Gulf of Mexico, with 3.48 ± 0.1 mm per year, and in the tropical North Atlantic, around Central America and the southern Caribbean, with 3.23 ± 0.1 mm per year (Figure 7b). The sea level on the Pacific side is rising at a lower rate than on the Atlantic side, with an increase of 2.23 ± 0.2 mm per year. Sea level on the Pacific side is highly influenced by ENSO, with more significant increases in sea level occurring during strong El Niño events and smaller increases during La Niña events.

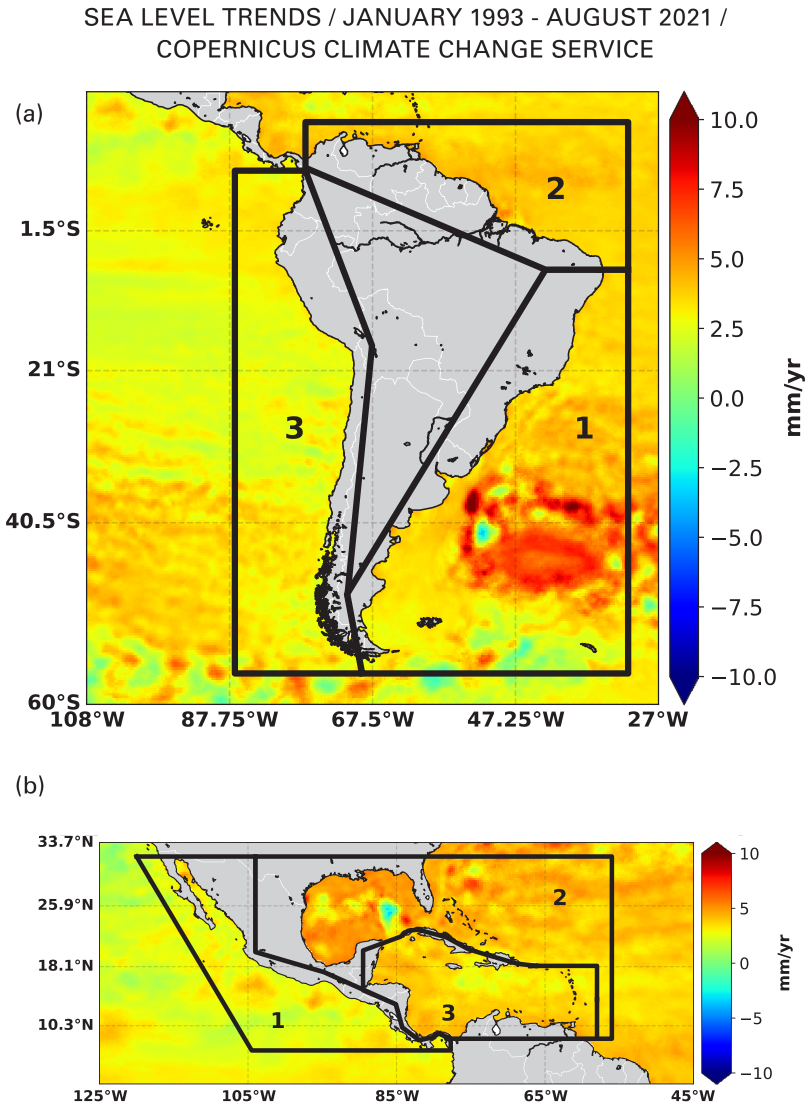


Figure 7. Regional sea-level trends in three domains for South America (a) and Mexico, Central America and the Caribbean (b), where the coastal sea-level trends from January 1993 to December 2021 were computed (based on satellite altimetry). Domain designations: a1 – South Atlantic, a2 – South America tropical North Atlantic, a3 – South America Pacific, b1 – Central America Pacific, b2 – subtropical North Atlantic and Gulf of Mexico, b3 – tropical North Atlantic.
Source: Copernicus Climate Change Service (C3S), https://climate.copernicus.eu/sea-level.

Extreme events

Although understanding broad-scale changes in the climate is important, the acute impacts of weather and climate are most often felt during extreme meteorological events such as heavy rain and snow, droughts, heatwaves, cold waves and storms, including tropical storms and cyclones. These can lead to or exacerbate other high-impact events such as flooding, landslides, wildfires and avalanches. This section provides an overview of the characteristics and selected impacts of these events, based largely on input from WMO Members. Additional information on socioeconomic impacts and risks associated with these events is provided in the section on Socioeconomic impacts.

The Working Group I contribution to the IPCC Sixth Assessment Report[24] indicated that global warming is altering the intensity and frequency of extreme weather, water and climate events. The report shows that for Central and South America the observed trends indicate a *likely* increase in the intensity and frequency of hot extremes and decrease in the intensity and frequency of cold extremes, as well as a significant intensification of total and heavy precipitation in south-eastern South America. As for droughts and dry spells, the report identified mixed trends in different subregions of the Caribbean and Central America, while in Mexico, central Chile and the Paraná–La Plata Basin there is some evidence of increased frequency and severity of meteorological droughts.

The following sections highlight the most impactful extreme events of the year. Additional reported events are included in an interactive online map provided separately.[25] The 1981–2010 climatological standard normal is used as reference, with any exceptions explicitly noted.

TROPICAL CYCLONES

The 2021 Atlantic hurricane season was very active, with 21 named storms – well above the 1981–2010 average of 14 – including seven hurricanes, of which four were major hurricanes. With about US$ 80 billion in damage (much of which occurred in the United States of America, associated with Hurricane *Ida*), it was also one of the costliest seasons. It was the sixth consecutive above-normal Atlantic hurricane season and the seventh consecutive year with a named storm forming before the official start to the season on 1 June (Tropical Storm *Ana* formed on 22 May). On 30 June, Tropical Storm *Elsa* (later Hurricane *Elsa*) became the earliest fifth named storm on record. Hurricane *Elsa* would become the first hurricane of the season on 2 July, and affected several territories in the Caribbean, including Barbados, Saint Lucia, Saint Vincent and the Grenadines, Martinique, the Dominican Republic, Haiti, Jamaica, the Cayman Islands and Cuba, before moving into Florida/United States.[26]

Three tropical cyclones were simultaneously active in the North Atlantic on 16 August, namely, Tropical Storm *Fred*, Tropical Storm *Grace* (later Hurricane *Grace*), and Tropical Storm *Henri* (later Hurricane *Henri*) (Figure 8). Tropical Storm *Fred* affected portions of the Greater Antilles (from 11 to 15 August), producing strong winds, some storm surge flooding, and heavy rainfall. Hurricane *Grace* made landfall on the Yucatán Peninsula of Mexico on 18 August, and after a trajectory over the south-western Gulf of Mexico, made a second landfall on the mainland coast of Mexico as a category 3 hurricane (on the Saffir-Simpson scale) on 20 August, making it the strongest hurricane on record to make landfall in the state of Veracruz.[27] At the time it was still a tropical storm, it affected the Leeward Islands, Puerto Rico, the Dominican Republic, Haiti (just days after a 7.2 magnitude earthquake), Jamaica and the Cayman Islands. The heavy rainfall and strong winds led to flash floods, landslides and damage to crops and infrastructure.

Hurricane *Ida* made landfall in western Cuba on 27 August with category 1 strength before rapidly intensifying into a category 4 hurricane on its track to Louisiana/United States. Before it developed into a tropical cyclone, rainfall associated with *Ida* caused significant flooding in the Bolivarian Republic of Venezuela.[28]

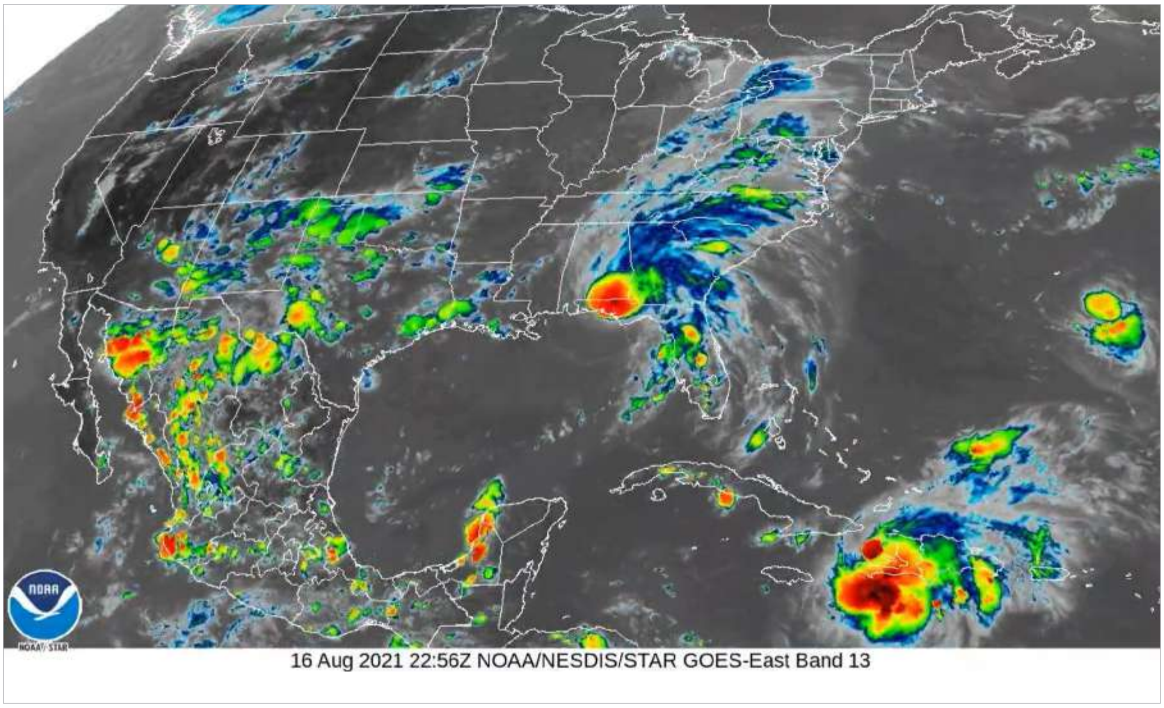


Figure 8. NOAA/NESDIS/STAR GOES-East Band 13 image of tropical cyclones simultaneously active in the North Atlantic on 16 August, 22:56 UTC: Tropical Storm *Fred* (centre), nearing landfall in the Florida Panhandle; Tropical Storm *Grace* (later Hurricane *Grace*) (bottom-right), south of Hispaniola; and Tropical Storm *Henri* (later Hurricane *Henri*) (centre-right), southeast of Bermuda.
Source: National Oceanic and Atmospheric Administration (NOAA).

HEAVY PRECIPITATION AND FLOODING

Central America and the Caribbean experienced abundant precipitation and subsequent flooding episodes associated with tropical cyclones. On Hispaniola, floods occurred on 1 July due to Tropical Storm *Elsa*, and later, on 12–19 August, Tropical Storms *Fred* and Grace caused additional floods. Tropical Storm *Grace* (later Hurricane *Grace*) passed over Haiti on 16 and 17 August, bringing heavy rain and strong wind to the country during the rescue efforts that followed the 7.2 magnitude earthquake on 14 August. The storm caused flash floods and landslides as it moved west past Haiti[29] and into the rest of the Caribbean.[30] Heavy rainfall in late November led to flooding in Cuba's eastern province of Holguín. The city of Moa, in Holguín, received 137 mm in 24 hours.[31] In Central America, flood events were reported in many places, at multiple times during the year, some associated with record short-term rainfall. Countries affected included Honduras, Guatemala, El Salvador, Costa Rica and Panama. In Turrialba, Costa Rica, on 22 and 23 July it rained 545 mm in 36 hours, a new record for such a period and almost double the average monthly rainfall for July (285 mm).[32] In Mexico, from 20 to 24 August, Tropical Storm *Grace* affected the Yucatán Peninsula and the state of Veracruz,[33] leaving 95% of the people of Poza Rica without electricity. A series of floods in Panama affected 27 500 people.

In South America, episodes of extreme rainfall triggered flooding and landslides that affected thousands of people, in particular in the state of Santa Catarina (southern Brazil), the state of Pernambuco (north-eastern Brazil), the northern section of the state of Minas Gerais and the southern part of the state of Bahia. The precipitation was about 200–250 mm above normal (1981–2010) in central Amazonia in December 2020–February 2021.[34] In the Brazilian Amazon, in Manicoré, in March, 583.8 mm of precipitation fell (normal is 300 mm), and in Tucuruí, 604 mm fell (normal is 436.7 mm).[35] As a result of these rainfall excesses, the Rio Negro at Manaus (central Brazilian Amazon) reached the highest water levels in 102 years of records in June 2021 (Figure 9). Since the late 1990s, nine extreme floods have occurred, while only eight events were reported from 1903 to 1998. The water level of the Rio Negro in Manaus was above 29 m (the emergency threshold) for 91 days. It reached 30.02 m on 16 June, breaking the previous record of 29.97 m in June 2012 (Figure 9). In Pedra Azul, state of Mato Grosso, accumulated precipitation in December was 707.5 mm, a new record for this station (the previous highest monthly value, recorded in 1961, was 488.3 mm, and the average value for December is 187.2 mm).[36] In French Guyana rainfall in 2021 was between 100% and 150% above normal. In Cayenne on 13 March it rained 70.4 mm in 1 hour, a once-in-a-hundred-year event,[37] and on 14 March it rained 134 mm in 3 hours in Matoury. Heavy rainfall and widespread floods hit all regions of Guyana towards the end of May, affecting more than 25 000 families and damaging at least 7 900 houses.[38]

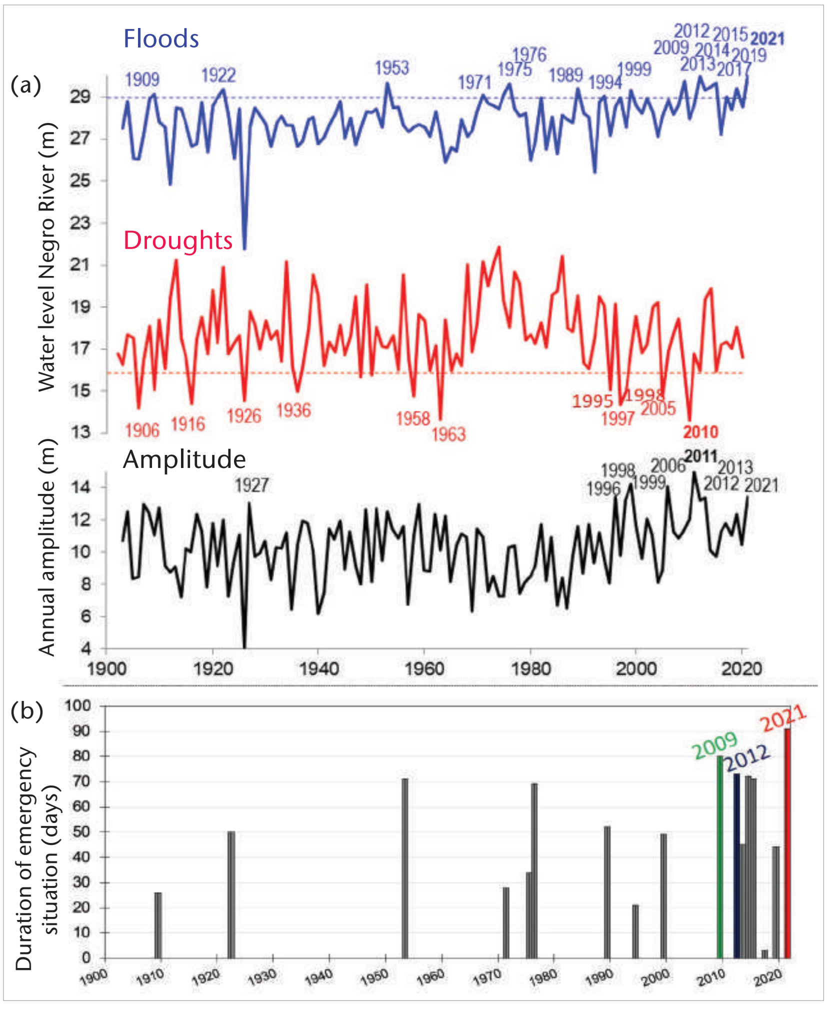


Figure 9. (a) Maximum (blue line) and minimum (red line) annual water level of Rio Negro at Manaus (1903–2021). Years corresponding to extreme flood with water level surpassing 29 m are indicated in blue, and years in red refer to severe hydrological droughts with minimum water level under 15.8 m. The annual water level amplitude (maximum minus minimum) is indicated by a black line (calendar years indicate extreme values with annual amplitudes >13 m) (adapted from Schöngart and Junk (2020));[39] (b) duration of the emergency in Manaus (water level ≥29.0 m). All data obtained from the platform Hidroweb, available on the National Water Resources Information System (SNIRH) operated by the Brazilian National Water and Sanitation Agency (ANA) and the Geological Survey of Brazil (CPRM). *Source:* Adapted from Espinoza et al. (2022).

In the Bolivarian Republic of Venezuela, on 23 August, the passage of tropical waves generated heavy rains that caused floods and landslides in the states of Mérida, Táchira, Bolívar, Apure, Zulia, Delta Amacuro, Carabobo, Yaracuy, Portuguesa and Sucre (Figure 10). The International Federation of Red Cross and Red Crescent Societies (IFRC)[40] reported that the impacts at the national level included nearly 55 000 people affected in 10 states and 85 municipalities, 116 roads and 10 bridges damaged, associated with 79 instances of rivers overflowing and 40 large-scale landslides. In the state of Mérida, heavy rainfall caused landslides and overflowing of rivers and streams, affecting 11 out of 23 municipalities.

Extreme rainfall and floods also occurred in other locations in southern South America, including in Dolores, Buenos Aires province, Argentina, where 276 mm of rain fell in 24 hours on 5 January, an unprecedented event which led to severe floods.[41] In the Juan Fernández Islands, administrative region of Valparaíso, Chile, 124 mm of rain fell on 19 April, the second highest 24-hour value for this station.[42]

In Colombia, floods were reported during 9–30 June and 19–24 September along the Magdalena River, 13–18 June along the Putumayo River, and 12–15 April in Cartagena affecting nearly 40 000 people.[43] In Llalli in the department of Puno in the southern Peruvian Andes, at 3980 m above sea level, a record daily rainfall of 58.8 mm was recorded on 9 February, surpassing the previous record of 45.7 mm on 26 February 2010 (average normal for February is 152.5 mm).

Floods during 13–20 February were reported in the Peruvian Amazon, and the flow of the Iñapari River reached 29 601.6 m^3/s on 20 February, surpassing the previous record of 18 357.2 m^3/s on 3 March 2017. Flooding was recorded on 13 February along the Pukiri and Colorado Rivers, and along the Tahuamanu River on 15 February. In Naranjitos, in the state of Amazonas, the flow of the Utcubamba River reached 673.8 m^3/s on 12 February, surpassing the flood limit value of 394.3 m^3/s.

Figure 10. Aerial view of flooded farms and houses in La Fortuna, state of Zulia, Bolivarian Republic of Venezuela, on 10 September 2021, two weeks after torrential rains hit the country. *Source:* Photo by Federico Parra/AFP via Getty Images.

DROUGHTS

Drought affected several countries in the LAC region during 2021. Drought categories based on the Integrated Drought Index (IDI)[44] have been used to describe the intensity of the drought in the three main affected countries/regions, Mexico, Chile and the Paraná–La Plata Basin. The IDI categories are D0: abnormally dry, D1: moderate drought, D2: severe drought, D3: extreme drought and D4: exceptional drought.[45,46]

According to the Drought Monitor of Mexico,[47] more than 50% of the country was affected by severe to exceptional drought in 2021, the second largest percentage after 2011/2012 (Figures 11 and 12). The area affected by drought since July 2020 reached 87.5% by the end of April 2021, leading to a water crisis and impacts on agriculture.[48] In 2020 and the first half of 2021, La Niña and a warmer tropical North Atlantic favoured increased precipitation in southern Mexico and drier conditions in the northern part of the country. The drought situation in northern Mexico in 2021 was due mostly to a weak monsoon season starting in July 2020. The negative rainfall anomalies in this region of Mexico shown in the annual rainfall map of Figure 4 are a result of warm and dry conditions that persisted until May 2021. After May 2021 the drought conditions gradually diminished (Figure 12).

By the middle of the year some parts of Central America were affected by weak-to-moderate drought. In the Caribbean, several countries experienced some level of moderate drought, particularly Haiti, the Dominican Republic, Puerto Rico and some parts of Cuba. Saint Croix, in the United States Virgin Islands, had its fourth driest year on record, with annual precipitation the lowest recorded since 1965, and groundwater levels were at record lows, similar to those of 2016.

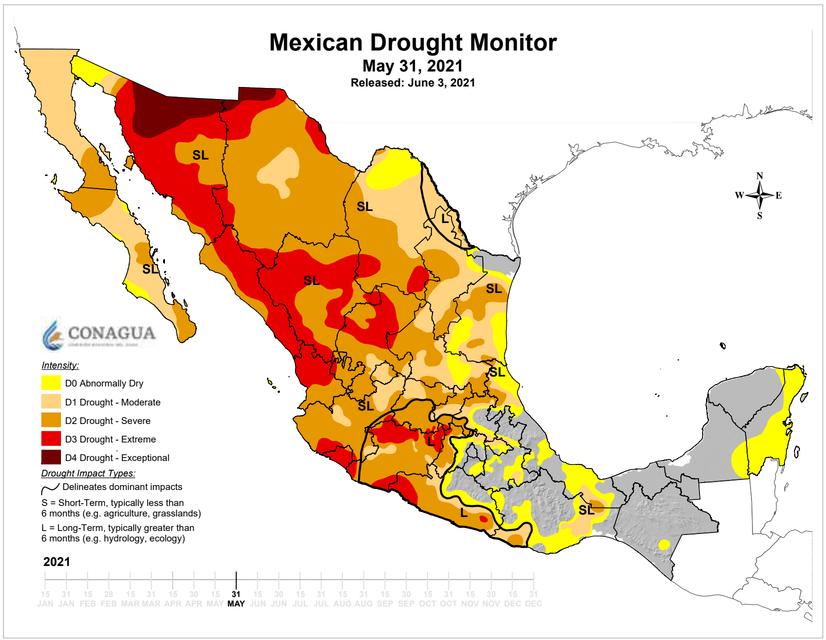


Figure 11. Drought conditions in Mexico, 31 May 2021.
Source: Drought Monitor of Mexico, National Water Commission (CONAGUA).

Drought also affected the west coast of subtropical South America, continuing an unprecedented, uninterrupted sequence of drier-than-average years in Chile. The ongoing "Central Chile Mega-drought", which has lasted for 13 years to date, is the longest and most severe in 1 000 years, putting Chile at the forefront of a regional water crisis (Figure 13).[49] The IPCC states that there is medium confidence that the drying trend in central Chile and severe droughts in south-western South America can be attributed to human influence.[50]

In the Paraná–La Plata Basin, the multi-annual drought affecting central-southern Brazil, parts of Paraguay and the Plurinational State of Bolivia continued in 2021 (Figure 13). The lack of rainfall, mainly in the upper part of the basin, has led to a considerable decrease in the flow of the Paraguay and Paraná Rivers (Figure 14). These drought conditions across the Paraná–La Plata Basin in Brazil and Argentina have been the worst since 1944.[51] In 2021 Brazil's south and south-east regions faced their worst droughts in nine decades, raising the spectre of possible power rationing given the grid's dependence on hydroelectric plants.[52] The drought situation in Paraná–La Plata Basin countries affected many sectors, including agriculture, inland water navigation, energy production, and water supply as well as ecosystems. Argentina, Brazil and Paraguay declared formal drought emergencies during 2021. On 24 July 2021, the Government of Argentina declared a state of water emergency valid for 180 days and encompassing seven provinces with territory along the Paraná, Paraguay and Iguazu Rivers. On 8 July 2021, the Government of Paraguay declared a state of emergency for navigation on the Paraná, Paraguay and Apa Rivers.[53]

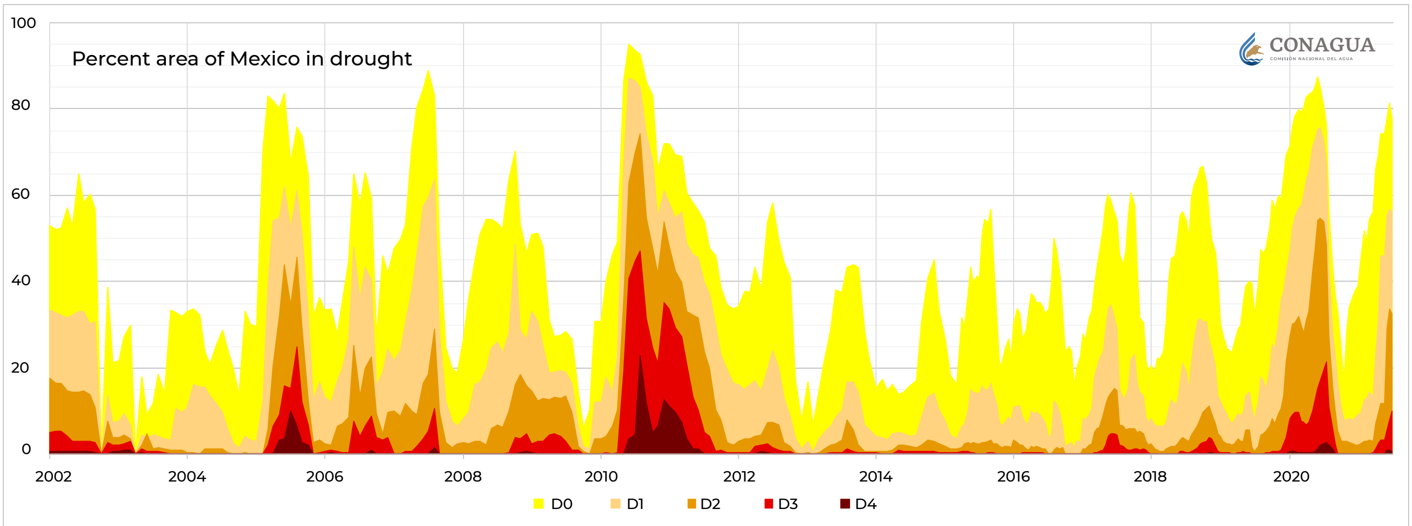


Figure 12. Percentage of territory affected by drought
(D0 – abnormally dry, D1 – moderate drought, D2 – severe drought, D3 – extreme drought, D4 – exceptional drought), in Mexico from 2003 to 2021.
Source: Drought Monitor of Mexico, CONAGUA.

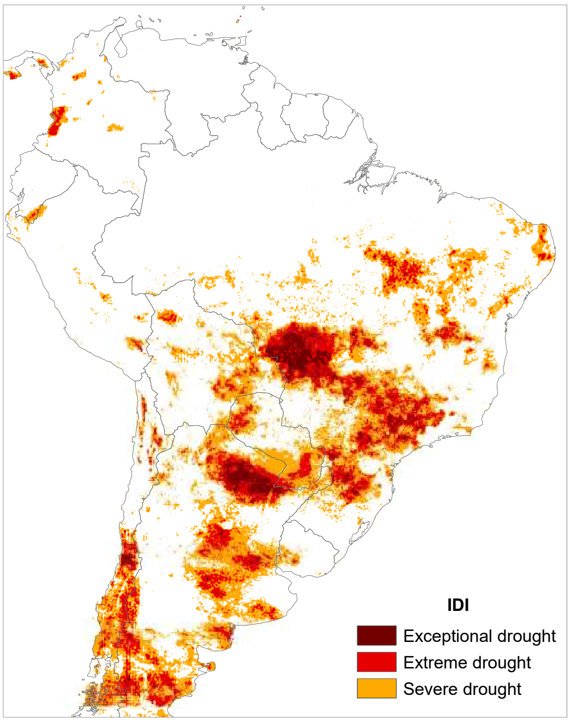


Figure 13. Integrated Drought Index (IDI) for September 2020–August 2021, in South America. *Source:* Standardized Precipitation Index (SPI) calculated from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and Vegetation Health Index from Center for Satellite Applications and Research (STAR/NOAA). Calculation based on Cunha et al. (2019).

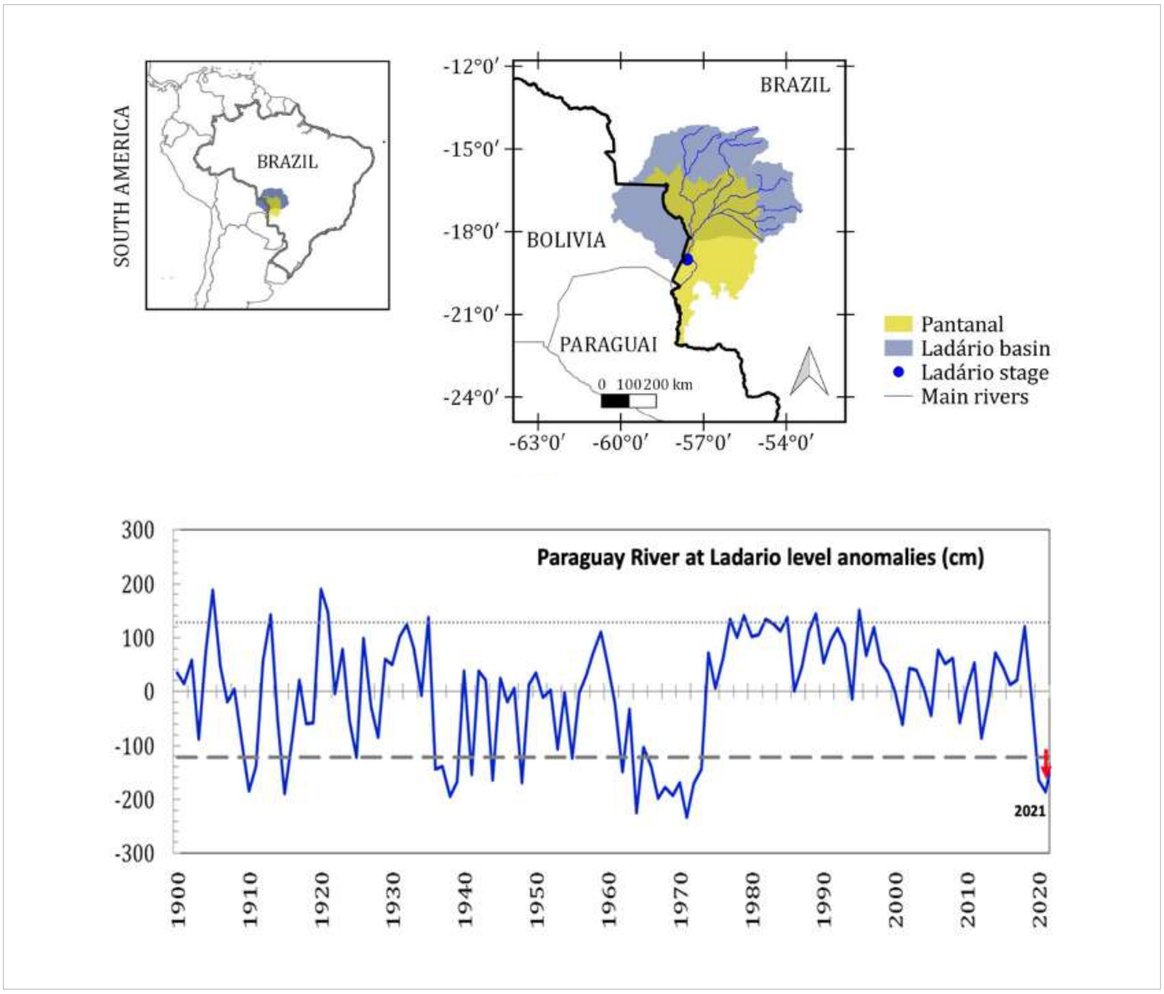


Figure 14. Level anomalies of the Paraguay River at Ladário (cm). Locations of the Ladário station and the Ladário Basin are shown in the right side of the panel. *Source:* Marengo et al. (2021).[54]

SANDSTORMS

On 1 October, sandstorms, rare in Brazil, hit several cities in various states of central and south-eastern Brazil, areas already affected by drought. In Três Lagoas (central Brazil), winds reached almost 70 km/h and were accompanied by a drop in temperature, from 41 °C to 24 °C, and low visibility caused by airborne sand. On 26 October, another large sandstorm, as well as smoke, hit the interior of São Paulo and areas of Mato Grosso. Within a week, this second dust storm left cities in São Paulo without power and in a state of emergency.

HEATWAVES AND WILDFIRES

Heatwaves were reported in many parts of the LAC region. In Argentina, several locations recorded 6–8 days in a row with heatwave conditions. An all-time temperature record was set in Cipolletti (43.8 °C) and Maquinchao (38.9 °C) on 22 January.[55] In west-central Brazil, in August 2021, exceptionally high temperatures were reported[56] over several days. For example, in Cuiabá, in the state of Mato Grosso, maximum temperatures reached 41 °C on 24 and 25 August (about 7 °C above normal), accompanied by critically low humidity levels, mainly in the central regions (relative humidity of approximately 8%–11%). On 21 September, Aragarças/Goiás reached 43.0 °C, the highest value for September at this station (the previous highest value was 41.5 °C on 14 September 2019). In Chile, up to 18 heatwave episodes during the year affected different regions of the country.[57] Some of them were very intense, including those that affected the Santiago region from 11 to 13 April (with a maximum temperature of 31.4 °C), and Valdivia from 2 to 5 February (37.3 °C) and then from 7 to 10 February (35.1 °C). On 27 February, Puerto Williams, Chile (considered the southern-most town in the world), registered its highest temperature on record, since 1961, of 26.1 °C (the previous record being 26.0 °C on 22 December 1984).[58] In Paraguay, a heatwave occurred from 18 to 20 September, with temperatures reaching 38.2 °C in Pedro Juan Caballero. In Peru, on 13 April, Jepelacio (northern Amazonia) reached 34.2 °C (the previous highest temperature was 33.6 °C on 23 November 2016).

Wildfires occurred all over South America during 2021 (Figure 15).[59] In Peru, on 5 August, forest fire driven by the low persistent humidity and the increase in the daytime temperature resulted in 2 200 hectares of natural vegetation

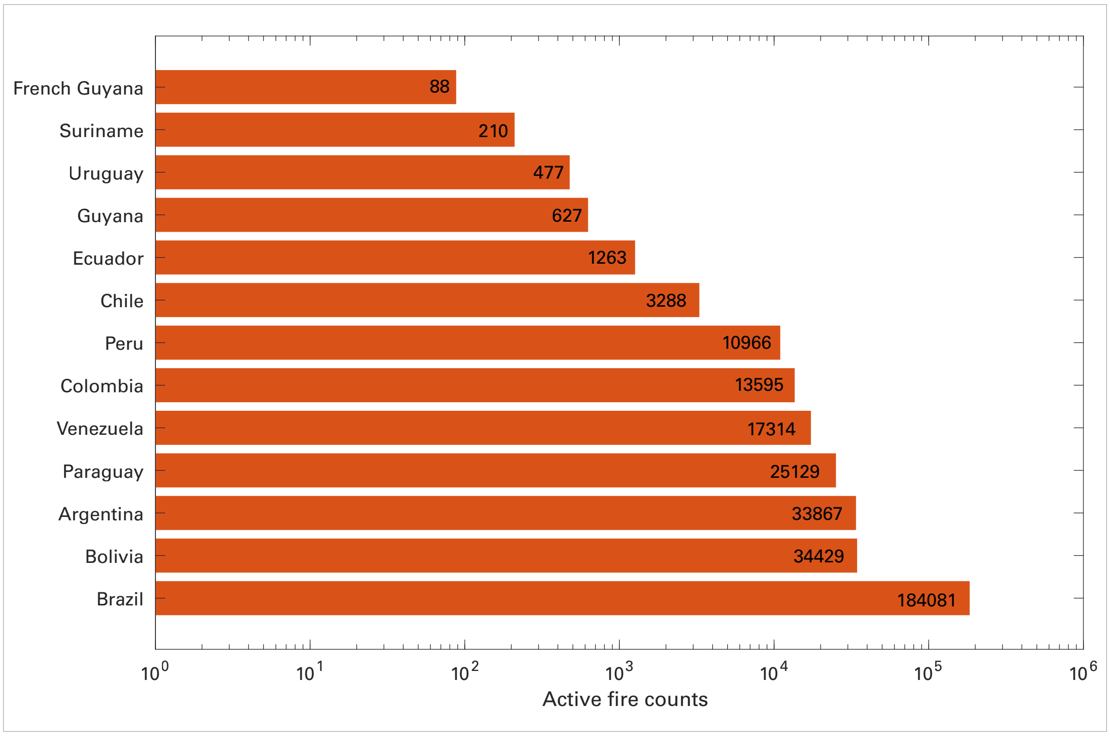


Figure 15. Number of active fires detected by MODIS-AQUA satellite in South America in 2021, by country or territory, displayed on a logarithmic scale.

cover being destroyed in the province of Quispicanchi, with 1 400 hectares and 800 hectares being destroyed in the districts of Lucre and Andahuaylillas, respectively.[60] Brazil reported approximately 184 000 fire outbreaks (of which 75 000 occurred just in the Brazilian Amazon). In August alone, more than 1 million hectares were burned in the Brazilian section of the Pantanal.[61] Most fires occurred in the Pantanal region of the state of Mato Grosso do Sul during compound drought and heatwave events, which enhanced vegetation flammability (Figure 16). It is estimated that wildfires burned more than 1 950 000 hectares across the Pantanal region during 2021 (Figure 16). Although these values correspond to a reduction of approximately 50% compared to 2020, the year 2021 still ranks as the second highest year since 2012 in terms of burned area.[62] Natural fires are rare in Brazil, and most fire outbreaks are associated with human activity, such as deforestation and pasture maintenance.[63]

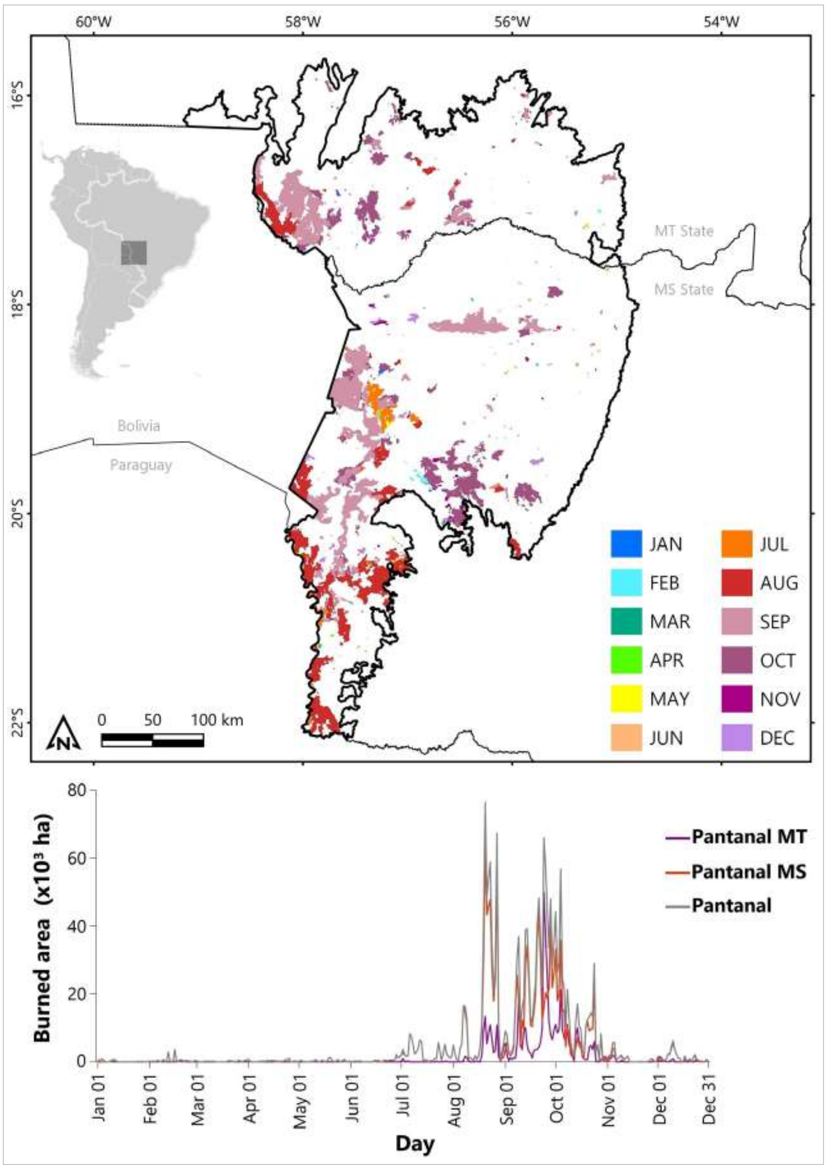


Figure 16. Burned areas in the Pantanal biome, Brazil, in 2021 (MT: state of Mato Grosso; MS: state of Mato Grosso do Sul).
Source: LASA-UFRJ.

COLD WAVES

Intense cold wave or cold spell episodes occurred during June and through August in many locations in southern South America. One of the most intense cold waves occurred in the last week of June into July, extending from western Amazonia and intensifying towards south-eastern Brazil, and with greater intensity in southern Brazil,[64] Paraguay, the Plurinational State of Bolivia, northern Argentina and central and southern Chile. In Argentina, on 28 June, Catamarca recorded its lowest minimum temperature of –6.2 °C (the previous record of –5.8 °C being on 15 June 1961).[65] On 29 July, minimum temperatures of –7.4 °C and –2.5 °C were detected in Presidente Roque Sáenz Peña and Formosa. These represent new monthly historical records, with the previous ones being –7.1 °C on 18 July 2017 and –2.3 °C on 1 July 1976, respectively. In the Plurinational State of Bolivia the all-time lowest temperatures were recorded in some stations of the Chiquitania and Pantanal regions and new historical minimum temperature records were set on 30 June. In Brazil, on 28 June , the temperature in Vilhena, in the state of Rondônia, reached 8.2 °C (compared with a 1981–2010 monthly average of 19.2 °C). In the Itatiaia National Park, in the highlands of Rio de Janeiro, the minimum temperature reached –9.9 °C on 1 July, about 25 °C below normal (14.4 °C), likely constituting one of the lowest minimum temperatures in Brazil in 2021. In Paraguay, between 28 and 30 June, the lowest temperatures on record were logged in Mariscal Estigarribia, where it reached –2.6 °C, and in Pedro Juan Caballero, where it reached 1.0 °C (the normal averages for June are 13.6 °C and 13.4 °C, respectively).

Climate-related impacts and risks

The COVID-19 pandemic negatively affected the economies of the countries in the region, especially the most vulnerable economies in the Caribbean small island developing states (SIDS). The state of the public finances, already weakened by the COVID-19 pandemic,[66] increased the risks to the countries of other disasters. The combined effect of COVID-19 and hydrometeorological hazards contributed to a slowing of progress towards achieving the Sustainable Development Goals (SDGs), and especially SDGs 1 and 2, no poverty and zero hunger.

AGRICULTURE AND FOOD SECURITY

According to the Food and Agriculture Organization of the United Nations (FAO),[67] negative impacts on harvests and/or changes in planting season (such as starting later than normal) were reported, due to below-average rainfall during the last quarter of 2021 in Chile, Brazil, Uruguay and Paraguay. The South American 2021 cereal harvest declined by an estimated 2.6% compared with the previous year. In the Caribbean, rice crops in some areas of Cuba were adversely affected due to rainfall deficits starting in April. In Haiti, irregular rainfall distribution in central areas affected crop growing conditions. Below-average rainfall between April and May 2021 in almost all of Haiti resulted in low agricultural production. Since late 2018, the number of Haitian people experiencing high levels of acute food insecurity (that is, Integrated Food Security Phase Classification (IPC) Phase 3 or above) has nearly doubled to about 4.3 million in September 2021–February 2022. Insecurity, poor production, natural disasters and inflation are key drivers of the current levels of acute food insecurity.[68]

In Central America, in 2021, the compound effect of the COVID-19 pandemic and hydrometeorological hazards – in particular, drought and flooding – had significant impacts on food security (see Figure 17). A total of 7.7 million people experienced acute food insecurity in El Salvador, Guatemala and Nicaragua.

Agriculture in Brazil, Chile, Paraguay and Uruguay was also affected due to the delay in the planting season as a result of below-average rainfall during the last quarter of 2021.[69] This shift in precipitation patterns was partly related to La Niña (see Precipitation and Sea-surface temperature).

In Brazil, the larger-producing summer crop suffered severe impacts from lack of rain during critical development stages and periods of frost (Figure 18) (see also Precipitation and Cold waves).

Paraguay is the world's fourth-largest exporter of soybeans, and this crop contributes greatly to the country's gross domestic product (GDP). Predictions of soybean production in Paraguay for 2020/2021 were reduced from 10 million tons to about 8 million tons. This was due to the lack of rainfall associated with La Niña. Rainfall in the Canindeyú and Itapúa departments during September and October 2020 was about 30% of normal.[70] The lack of rainfall affected the yields of short-cycle soybean, sown at the beginning of 2021. In the department of Alto Paraná, short-cycle soybean was expected to be almost completely lost. A similar decrease in the sown area and yields of short-cycle

Figure 17. Corn field affected by drought (left) and damage to corn cob (right) in Jocotán, Chiquimula, Guatemala, 12 July 2015. Recurrent droughts leading to crop losses in the Central American Dry Corridor, comprised of El Salvador, Guatemala, Honduras and Nicaragua, severely affect rural livelihoods and increase food insecurity in the region. Photo credit: Rubí López. *Source:* FAO Americas, https://www.flickr.com/photos/faoalc/27117133485/in/album-72157668276602532/.

soybean also occurred during the previous 2019/2020 cropping cycle.[71]

In Argentina, lack of February rains, as well as high temperatures affected the late-planted crop (usually the smaller season) during critical developmental stages. Many crop sowings had shifted to the late-planted season, making the two seasons about the same size in 2021. The Grain Exchange (Bolsa de Cereales) of Buenos Aires (Argentina) stated that the production of soybean in the 2020/2021 cropping cycle was about 43.5 million tons, about 3 million tons below forecasts. The decrease in production – 11% lower than in 2019/20 – was tied to low rainfall during February and March 2021, critical periods for yield definition of this crop. Nationally averaged soybean yields for Argentina were about 10% lower than the 2019/2020 cycle.[72] Reduced soybean production prospects in South America are contributing to the sharp increase in the FAO vegetable price index.[73]

Reduced precipitation and altered rainfall seasons are also affecting rainfed subsistence farming, particularly in the Dry Corridor in Central America and in the tropical Andes, compromising food security in this region.[75]

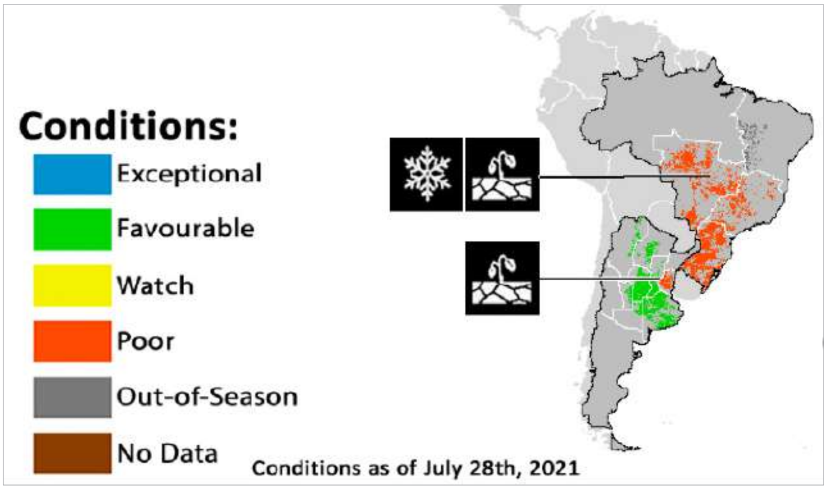


Figure 18. Maize crop conditions in main growing areas are based upon a combination of national and regional crop analysis inputs along with Earth observation data. Condition information is based upon information as of 28 July. Where crops are in other than favourable conditions, the climatic drivers responsible for those conditions are displayed.[74]

In Chile, the continuing drought and loss of surface and underground water resources severely affected dozens of rural communities, requiring water to be supplied by trucks.

According to the IPCC, there is high confidence that drought severity and intensity will increase, and that soil moisture will decline in south-western South America, south-western North America, south-western Australia, Central America and the Amazon Basin. These regions are expected to become drier due to both reduced precipitation and increases in evaporative demand.[78]

WATER RESOURCES

Glacier retreat, temperature increase and precipitation variability, together with land-use change, have affected ecosystems, water resources and livelihoods, throughout the LAC region, including through landslides and flood-related disasters.[76] Mexico continues to be affected by recurrent droughts in large parts of its territory. Several countries of the Caribbean have dealt with severe lack of water (see Droughts).

The Paraná River, on which Argentina relies to export 80% of its agricultural products, was affected by low water flow due to the Paraná–La Plata Basin drought.[77] Electricity production was also affected due to drought-induced low water levels at the Yacyretá and Itaipú Dams in Paraguay. The worst drought situation in decades in Brazil's south and south-east regions also negatively affected hydroelectric power generation (see Droughts).

FOREST AND ECOSYSTEM SERVICES

Central and South American ecosystems are highly exposed and vulnerable to climate change. The combined effect of anthropogenic land-use changes and climate change has increased the vulnerabilities of terrestrial ecosystems. Extreme heat and drought, leading to wildfires, damage the forest and related ecosystems.

The Amazon forest was exposed to unprecedented droughts and higher temperatures in 1998, 2005, 2010 and 2015/2016, mainly attributed to El Niño. Cumulative drought impacts have adversely affected forest health. Deforestation in the Brazilian Amazon rainforest area was 12 000 km^2 in 2021, reaching its highest value since 2009 (Figure 19). The deforested area increased by 22% from 2020 to 2021 and doubled compared to the annual average of deforested area during the 10-year period 2009–2018.

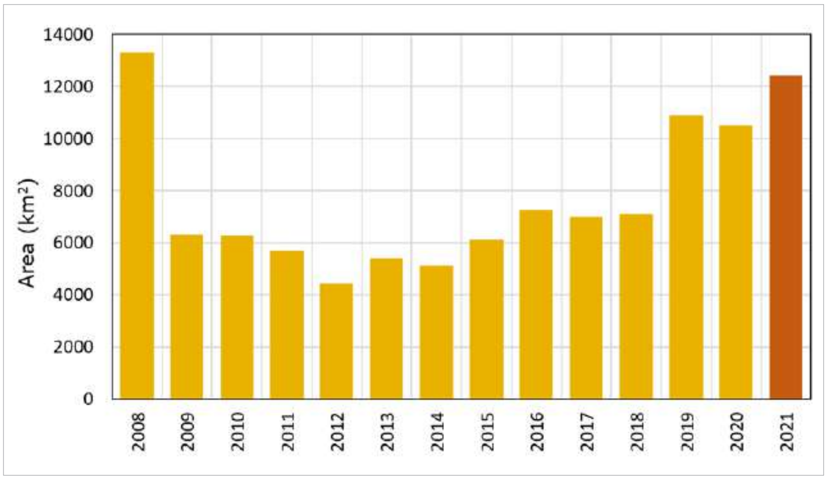


Figure 19. Annual deforestation rate in the Brazilian Amazon from 2008 to 2021.
Source: PRODES-INPE[79] -National Institute for Space Research.

Similarly, ocean and coastal ecosystems such as coral reefs, estuaries, salt marshes, mangroves and sandy beaches are negatively affected by climate change and associated hazards in the region.[80]

Much of the coastal area surrounding the Mesoamerican Reef and nearby islands is low-lying and exposed to sea-level rise. Eroding shorelines have already been documented, which can affect nesting and reproductive success of marine turtles. In addition, the warming of seawaters is responsible for the observed increase in episodes of coral bleaching, which is devastating to reefs and the wildlife that depend on them.

Ongoing coral reef restoration projects in Spanish-speaking countries in the Caribbean and eastern Tropical Pacific are being developed. These aim to provide alternative, sustainable livelihood opportunities for local populations, and to promote coral reef conservation for re-establishing a self-sustaining, functioning reef ecosystem.[81] This may have strong positive impacts on tourism, local economies, fisheries and food security for local populations.

MIGRATION AND POPULATION DISPLACEMENT

Migration and displacements have multiple causes. Climate change and extreme events are amplifying factors, which exacerbate social, economic and environmental drivers. According to the Working Group II contribution to the IPCC Sixth Assessment Report,[82] changes in climate and extreme events have severely affected the LAC region. The Andes, north-east Brazil and the northern countries in Central America are among the regions most sensitive to climatic-related migrations and displacements, a phenomenon that has increased in the last eight years, compared with the situation described in the IPCC Fifth Assessment Report (2014).[83] On small islands, the vulnerability of communities, especially those relying on coral reef systems for livelihoods, may exceed adaptation limits well before 2100. The impacts of climate change on vulnerable low-lying and coastal areas present serious threats to the ability of land to support human life and livelihoods. Although the drivers and outcomes are highly context-specific, climate-related migration is expected to increase on small islands, including in the Caribbean region.

The southern and coastal areas of Suriname bore the brunt of heavy rainfall recorded in 2021, with flooding displacing some 1 000 households and creating priority food security needs[84] (see Precipitation and Heavy precipitation and flooding). The 2021 Atlantic hurricane season triggered fewer displacements than the 2020 season. However, thousands of people in Cuba were evacuated in July and August 2021 as Hurricanes *Elsa* and *Ida* affected the island.[85] Protracted weather- and climate-related displacement remains a major concern in the region. Cross-border migration has been reported in Central America subsequent to the impacts of Hurricanes *Eta* and *Iota* in late 2020.

According to the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center,[86] the flooding resulting from Tropical Storm *Fred* affected the Dominican Republic. The floods left 47 communities across the country cut off, and damaged or destroyed over 800 homes, as well as displacing over 4 000 people. In Haiti, strong winds, heavy rainfall and flooding associated with Hurricane *Grace* worsened the ongoing humanitarian crisis that followed the 7.2 magnitude earthquake on 14 August, by destroying makeshift shelters and interrupting rescue and recovery efforts.[87]

According to the latest analysis by the International Organization for Migration (IOM), extreme climate events and slow onset climatic change influenced human mobility patterns throughout 2021.[88] In December 2021, more than 90 000 people were evacuated and displaced in the states of Bahia and Minas Gerais in Brazil, as a consequence of extreme flooding that led to the collapse of two dams[89] (see Heavy precipitation and flooding).

Several countries in the LAC region adopted/updated their nationally determined contributions (NDCs) to the Paris Agreement to incorporate human mobility issues.[90] For instance, the 2021 updated NDC from Antigua and Barbuda calls for the "potential adoption of Organization of Eastern Caribbean States (OECS) regional agreements, frameworks and policies on forced displacement and human mobility caused by climate change within the OECS region". The 2021 Belize updated NDC suggests enhancing the protection of "climate refugees". The Paraguay 2021 NDC requests an enhanced involvement with the IOM to address hazards that cause "forced displacement and migration".

SOCIOECONOMIC IMPACTS

According to the latest analysis[91] of the Economic Commission for Latin America and the Caribbean (ECLAC), extreme events, in particular persistent drought, have exacerbated the damaging impact of the COVID-19 pandemic on the social and economic prospects of the countries in the region, especially the Caribbean small island developing states (SIDS). The tourism sector, a key driver of economic growth in those countries, came to a complete halt across the economy. The accumulated losses of this sector in the Caribbean are anticipated to range between US$ 53 billion and US$ 75 billion during the period 2020 to 2023. This subregion will be, relatively, the most affected in the LAC region, given its smaller population and the weight of tourism in its economies, and the losses will have negative consequences on the level of employment in the sector, with a gender bias.

Brazil was severely damaged by extreme weather and climate at various times of the year, leading to several US$ billions of losses and disruption of roads and schools. According to the Instituto de Desenvolvimento Agropecuário e Florestal Sustentável do Estado do Amazonas (IDAM),[92] the flood in the Brazilian Amazon led to an estimated economic loss of US$ 40 million for the rural sector and affected more than 450 000 people in the state of Amazonas.

The flood disaster in the states of Bahia and Minas Gerais in Brazil resulted in an estimated loss of US$ 3.1 billion. The total affected population is estimated at more than 800 000.[93, 94, 95]

Preliminary estimates from the Brazilian government's food supply agency (CONAB)[96] indicate that extreme cold conditions and frosts (see Extreme events) affected 150 000 to 200 000 hectares – about 11% of the country's total arabica crop area. Frost-related losses, together with accumulated losses from the 2021 drought, ranked among the biggest disasters for Brazilian farmers in recent years. CONAB estimates that coffee production in Brazil in 2022 will be 120 000 tons lower than what was forecast in May 2021, due to three cold waves and drought in 2021. The sugar-energy sector had also already been accumulating losses since 2020 due to drought. CONAB estimates the 2022 sugarcane harvest at 574.8 million tons, 4.6% lower than the previous harvest.

Sargassum, climate change and the impact on tourism in the Caribbean

Sargassum is brown algae which originates in the Sargasso Sea of the western Atlantic Ocean. It grows up to several metres and can float in the open ocean. Seawater warming due to climate change is among the factors responsible for its spread in the Caribbean.[97]

Floating sargassum is beneficial at sea, mainly as a unique pelagic habitat. However, its drifting to and accumulation on the coastlines has significant negative impacts on tourism and other biophysical and socioeconomic sensitive sectors. This issue therefore represents an emerging hazard for the Caribbean

Figure 20. Drone photograph of a vast mat of sargassum near Silk Cayes, Belize, 4 September 2018. Photo credit: Tony Rath. *Source:* UNEP-CEP, 2021.

countries, which are already subject to numerous others. Indeed, various countries in the Caribbean have declared national states of emergency with respect to sargassum influxes (Figure 20).[98]

The year 2021 witnessed another washing up of massive quantities of sargassum in the Caribbean region. Warming oceans due to climate change and other environmental conditions, including undetermined potential factors, lead to massive quantities of sargassum being transported to coastlines in the Caribbean (West Africa is also affected).[99] This in turn reduces economic activities in climate-sensitive sectors such as tourism, maritime transport and fisheries, and adversely affects ocean biodiversity and human well-being.[100]

Enhancing climate resilience and adaptation policies

REASONS FOR CONCERN AND KNOWLEDGE GAPS

The IPCC Sixth Assessment Report Working Group I[101] and Working Group II[102] reports conclude that the LAC climate is changing. Precipitation patterns are shifting, temperatures are rising and some areas are experiencing changes in the frequency and severity of weather extremes, such as heavy rains. The effects range from melting Andean glaciers to devastating floods and droughts. The two great oceans that flank the continent – the Pacific and the Atlantic – are warming and becoming more acidic, while sea level also rises. Unfortunately, greater impact is likely in store for the region as both the atmosphere and oceans continue to rapidly change. Food and water supplies will be disrupted. Towns and cities and the infrastructure required to sustain them will be increasingly at risk. Human health and welfare will be adversely affected, along with natural ecosystems. Amazonia, north-eastern Brazil, Central America, the Caribbean and some parts of Mexico will see increased drought conditions, while hurricane impacts may increase in Central America and the Caribbean. Climate change is threatening vital systems in the region, such as the glaciers in the Andes, the coral reefs in Central America and the Amazon forest, which are already approaching critical conditions under risk of irreversible damage.

In addition to impacts from the COVID-19 pandemic, the United Nations Office for Disaster Risk Reduction (UNDRR) registered a total of 175 disasters in the LAC region during the 2020–2022 period.[103] Of these, 88% have meteorological, climatological and hydrological origins. These hazards accounted for 40% of recorded disaster-related deaths and 71% of the economic losses. The UNDRR *GAR Special Report on Drought 2021*[104] documents the severity of impacts of recurrent droughts in the Caribbean, in the years 2009–2010, 2014–2016 and 2019–2020. Those droughts have had severe, long-term and cascading health and sanitation, economic, social and environmental impacts, and have also generated secondary hazards, such as wildfires.

The tourism sector is highly vulnerable to climate change and at the same time contributes to the emission of greenhouse gases which cause global warming. Accelerating climate action in tourism is therefore of utmost importance for the resilience of the sector. Climate action is understood as the efforts to measure and reduce greenhouse gas emissions and strengthen adaptive capacity.

The IPCC has indicated (2022)[105] that the most reported obstacle for adaptation in terrestrial, freshwater, ocean and coastal ecosystems in the region is financing, but other challenges exist. For example, adaptation barriers in the water sector include institutional instability, fragmented services and poor management of services, inadequate governance structures, and insufficient data and analysis of adaptation experience.

IMPROVING MULTI-HAZARD RISK-INFORMATION SYSTEMS, CLIMATE POLICY AND CLIMATE SERVICES

The intense rainfall and floods in the states of Bahia and Minas Gerais in Brazil during the last week of December 2021 were properly monitored, and alerts helped minimize related damage and protect human lives and property. Loss of life in this disaster was lower than in previous disasters despite higher accumulated rainfall.[106] This example highlights the importance of having appropriate early warning services.

The importance of strengthening climate services, including but not limited to early warnings, is increasingly recognized in the region. NDCs submitted by countries as part of implementation of the Paris Agreement outline efforts by each country to reduce national emissions and adapt to the changing climate. In the LAC region, 30 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) had submitted NDCs as of March 2022. Of those, 24 have submitted a new, updated or second NDC.

Most Parties have highlighted agriculture and food security, water, health and ecosystem and biodiversity as their top areas for adaptation (Figure 21a). Over 80% of Parties in the region have prioritized climate services in their NDCs. Climate services capacity development

(40%), modelling and forecasting (36%), data and data management (32%), observing network (32%), monitoring and evaluation (31%) and research (20%) were the topics most mentioned among those NDCs (Figure 21a). Over 60% of Parties in the region have included gender-related issues in their NDCs.

Over 60% of NDCs from the region mention early warning (EW) in their NDCs – for droughts, floods, storms and heat and cold waves. For example, Belize[107] highlighted the need to enhance early warning systems for drought and extreme weather events to support farmers in planning for and responding to the impacts of climate change by 2025. Floods, tropical cyclones, droughts, sea-level rise, temperature increases and changes in precipitation patterns have been mentioned by most Parties as hazards of the highest concern (Figure 21b).

MEMBERS' CAPACITIES: CLIMATE SERVICES AND EARLY WARNING

Disasters expose inequalities in natural and managed systems and human systems as they disproportionately affect poor and marginalized communities including ethnic and racial minorities, indigenous people, women and children. Therefore, disaster risk reduction is fundamental for climate justice and climate-resilient development. In Central and South America, climate change will increase water and food security risks due to frequent/extreme droughts, and damages to life and infrastructure due to floods, landslides, sea-level rise, storm surges and coastal erosion. Floods and landslides pose a risk to life and infrastructure; a 1.5 °C temperature increase would increase the population affected by floods by 100%–200% in Colombia, Brazil and Argentina, by 300% in Ecuador and by 400% in Peru. Increased water scarcity and competition over water are projected with high confidence by the IPCC.[108]

In the context of significant weather and climate hazards under climate change scenarios, some extreme weather events increase in frequency and/or severity because of climate change.[109] Disasters associated with these hazards demonstrate the immediate societal and political implications of rising risks, and provide windows of opportunity to raise awareness about climate change and to implement disaster reduction policies and strategies. Meeting the SDG 11 (sustainable cities and communities) targets of reduced loss of life and economic losses will require reducing climate-related disaster impacts.

To reduce adverse impacts of climate-related disasters and support resource management decisions and improved outcomes, climate services, end-to-end early warning systems and sustainable investments are required but are not yet adequate.

Although climate services are explicitly mentioned in most Parties' NDCs as a requirement for managing climate risks in climate-sensitive sectors, WMO data indicate that one WMO Member in the LAC region is at a less-than basic capacity level for the provision of climate services, six are at a basic level, and eleven Members have an essential capacity level only. Just five WMO Members fall into the full or advanced capacity categories (Figure 21c).[110]

As defined by the UNDRR, multi-hazard early warning systems (MHEWS) are:

> an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events.[111]

MHEWS data from WMO Members suggest that the LAC region faces several EW capacity gaps.[112] According to data from 19 WMO Members in the LAC region that responded to the 2020 WMO Hydrology Survey, 16 provide forecast and warning services for riverine floods, 12 for flash floods, and 13 for droughts. However, 12 Members out of the 19 WMO LAC Members that provided data reported having inadequate end-to-end flash flood forecasting and warning services and 8 Members reported having inadequate riverine floods forecasting/warning services, even though floods are frequent in the region (Figure 21f). Moreover, 9 Members from the region provide end-to-end drought forecasting and warning services at an inadequate capacity level. More investment – and more precisely targeted investment – in climate services is needed to strengthen MHEWS and decision support for adaptation in climate-sensitive sectors prioritized in the NDCs of Parties to the UNFCCC.

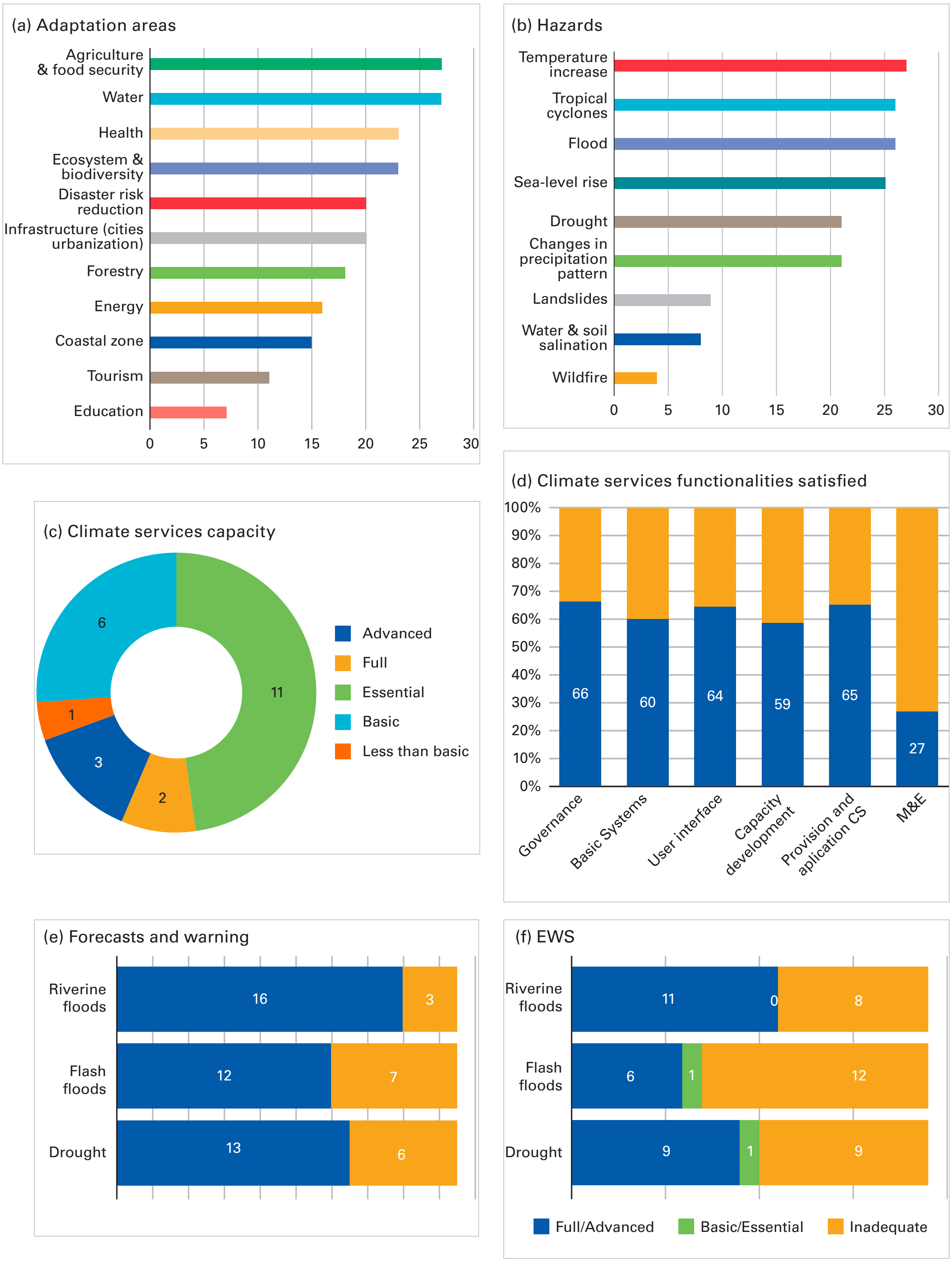


Figure 21. Overview of LAC climate policy priorities and capacities for climate services and early warning systems. Note to Figure 21(d): the results are representative of ten SIDSs that provided data. M&E: Monitoring and Evaluation of socioeconomic benefits. Note to Figure 21 (e): the results are representative of seven SIDSs that provided data. Grey represents WMO Members indicating no EWS in place.[113] Note to Figure 21(f): Member capacities are categorized as Inadequate (0%–33%), Basic/Essential (34%–66%) and Full/ Advanced (67%–100%), according to the estimated percentage of the at-risk population that receive EW. For each hazard, the Inadequate category includes Members (providing data) reporting that no end-to-end EWS for the hazard is in place, as well as those whose end-to-end EWSs do not reach more than 33% of the at-risk population. The results are representative of seven SIDSs that provided data.[114]

Observational basis for climate monitoring

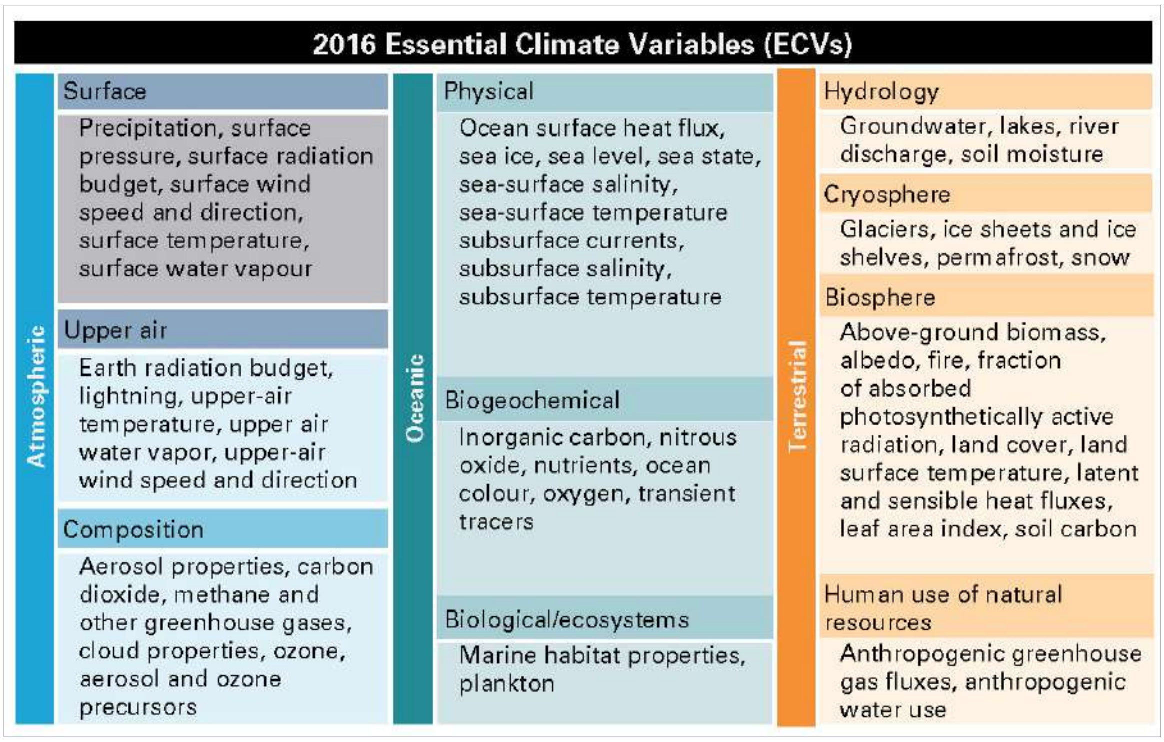
Climate monitoring is performed by a network of observing systems covering the atmosphere, the ocean, hydrology, the cryosphere and the biosphere. Each of these areas is monitored in different ways by a range of organizations. Cutting across all these areas, satellite observations provide major contributions to global climate monitoring.

In 1992, the Global Climate Observing System (GCOS) was established jointly by WMO, the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC) to coordinate and facilitate the development and improvement of global climate observations. GCOS has identified a set of Essential Climate Variables (ECVs)[115] that together provide the information necessary to understand, model and predict the trajectory of the climate as well as plan mitigation and adaptation strategies.

ECVs are physical, chemical or biological variables or a group of linked variables that critically contribute to the characterization of Earth's climate system, and include atmospheric, oceanic and terrestrial components. GCOS currently specifies 54 ECVs (see Figure 22).

ECV data sets provide the empirical evidence needed to understand and predict the evolution of climate, to guide mitigation and adaptation measures, to assess risks and enable attribution of climate events to underlying causes, and to underpin climate services. They are required to support the work of the UNFCCC and the IPCC.

Figure 22. Essential Climate Variables (ECVs) identified by GCOS



Data sets and methods

TEMPERATURE

Six data sets (cited below) were used in the calculation of regional temperature. Regional mean temperature anomalies were calculated relative to 1961–1990 and 1981–2010 baselines using the following steps:

1. Read the gridded data set;

2. Regrid the data to 1° latitude × 1° longitude resolution. If the gridded data are higher resolution, then take a mean of grid boxes within each 1°×1° grid box. If the gridded data are lower resolution, then copy the low-resolution grid box value into each 1°×1° grid box that falls inside the low-resolution grid box;

3. For each month, calculate the regional area average using only those 1°×1° grid boxes whose centres fall over land within the region;

4. For each year take the mean of the monthly area averages to get an annual area average;

5. Calculate the mean of the annual area averages over the periods 1961–1990 and 1981–2010;

6. Subtract the 30-year period average from each year to get anomalies relative to that base period.

Note that the range and mean of anomalies relative to the two different baselines are based on different sets of data, as anomalies relative to 1961–1990 cannot be computed for ERA5 which starts in 1979.

The following six data sets were used:

Berkeley Earth – Rohde, R. A.; Hausfather, Z. The Berkeley Earth Land/Ocean Temperature Record. *Earth System Science Data* **2020**, *12*, 3469–3479. https://doi.org/10.5194/essd-12-3469-2020.

ERA5 – Hersbach, H.; Bell, B.; Berrisford, P. et al. The ERA5 Global Reanalysis. *Quarterly Journal of the Royal Meteorological Society* **2020**, *146* (730), 1999–2049. https://doi.org/10.1002/qj.3803.

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PRECIPITATION

Precipitation in situ data from National Meteorological and Hydrological Services.

GLACIERS

Glacier mass balance data for 22 monitored glaciers in the Andes from the World Glacier Monitoring Service (WGMS), https://www.wgms.ch.

SEA-SURFACE TEMPERATURE

Sea-surface temperature anomalies processed by CIIFEN from NOAA/NCEP Global Ocean Data Assimilation System (GODAS).

SEA LEVEL

Regional sea-level trends based on C3S altimetry data averaged from 50 km offshore to the coast by the Laboratory of Space Geophysical and Oceanographic Studies (LEGOS).

DROUGHT

Integrated drought index (IDI) uses SPI data calculated from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and Vegetation Health Index from Center for Satellite Applications and Research (STAR/NOAA).

Standardized Precipitation Index (SPI) in situ data from National Meteorological and Hydrological Services.

WILDFIRES

Burned areas in Pantanal: NASA satellite images (NPP-VIIRS) processed by ALARMES warning system from the Laboratory for Environmental Satellite Applications (LASA-UFRJ).

Active fire data for South America (Figure 15): NASA satellite images (MODIS-AQUA) processed by the Brazilian National Institute for Space Research (INPE).

CLIMATE SERVICES

WMO Analysis of NDCs

Checklist for Climate Services Implementation (Members' climate services capacity, based on responses to this Checklist, can be viewed here)

WMO Hydrology Survey, 2020

2020 State of Climate Services: Risk Information and Early Warning Systems (WMO-No. 1252)

2021 State of Climate Services: Water (WMO-No. 1278)

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Endnotes

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ANEXO 5

The 2022 South America report of The *Lancet* Countdown on health and climate change: trust the science. Now that we know, we must act

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Executive summary

The health of South American populations is being severely impacted by increasing climate change-driven environmental changes. Exacerbated by increased social inequities and vulnerability, deforestation, land degradation, and global climate variabilities in sea temperature, can potentially lead to extreme weather and climate events, magnifying the negative effects of climate change on health. Understanding the direct and indirect exposure routes to climate hazards and the effects on health and wellbeing is critical to design successful and effective evidence-based adaptation and mitigation plans and policies.

This report is part of the *Lancet* Countdown's broader efforts to develop expertise and understanding of the links between health and climate change at the regional level. The *Lancet* Countdown South America (LCSA), a newly launched chapter of the *Lancet* Countdown, is an independent, multidisciplinary academic collaboration dedicated to tracking the links between public health and climate change in South America (SA). This collaboration brings together 21 academic institutions and UN agencies with 28 researchers representing various disciplines. The data and results provided in this report for the 12 countries of the region,* explore in regional detail the results of the 2022 global *Lancet* Countdown report and provide the evidence to support targeted response strategies for decision-makers. Its findings and conclusions represent the

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Note: This summary is available in Spanish and Portuguese in the Supplementary data.

*The 12 countries considered in this report are: Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, Guyana, Paraguay, Peru, Uruguay, Venezuela, and Suriname. French Guiana has not been considered in this report, as it is an overseas department of France.

consensus of experts across multiple fields, covering 25 indicators summarised below in four key messages.

Climate change is harming the health of South Americans, it's time to take prompt action

The adverse health effects of climate change are accelerating and disproportionately affecting the most vulnerable populations in SA. For the past ten years, populations in every country in the region have seen their health increasingly affected by climate change-related hazards. This trend will only continue if prompt action is not taken.

In the last ten years, the more frequent and intense heatwaves have increasingly put the health and survival of children under one year old and adults above 65 years at risk. On average, children <1 year were exposed to 2.35 million more person-days of heatwaves each year, and adults above 65 years exposed to 12.3 million more person-days, as compared to a 1996–2005 baseline (indicator 1.1.1). Since the year 2000, the estimated number of heat-related deaths has increased continuously among people over 65 in almost all countries. Brazil, Argentina, Colombia, and Venezuela were the most affected countries in the region (indicator 1.1.2). The monetised value of this heat-related mortality of older adults in SA was estimated as the equivalent of the average income of 485,000 local workers in 2021 (indicator 4.1.1).

In addition, the high temperatures are increasingly limiting the productivity of labourers in SA, undermining people's livelihoods, and compounding the impacts of the economic crisis now affecting many countries in the region. Indeed, the potential regional income loss associated to heat-related reduction in labour productivity in 2021 was USD 22 billion with the construction and agricultural sectors being the most severely affected, incurring 68% of the total losses in the region (indicator 4.1.2).

Population exposure to wildfire danger has increased in the past decade driven by the high temperatures and increased incidence of drought in many areas, making wildfire occurrence and spread more likely, and hampering control efforts. This is particularly relevant in SA, which faces a dangerous interplay between intentional human-made wildfires -more closely linked to land use changes and deforestation, as in the Amazon, the Pantanal, and El Chaco -as well as climate-driven ones, such as the 2022's wildfire in Argentina, and Paraguay. Regionally, the population exposure to very high or extremely high wildfire danger in SA has increased in nine of out 12 countries, with a regional average increase of seven more days in 2018–2021 compared to the baseline. However, the number of exposure days across countries vary, Uruguay, Paraguay saw an increase of 3-4 exposure days, vs Argentina and Chile 14–20 days of exposure (indicator 1.2).

Of particular concern in SA, where 168.7 million people are affected by moderate or severe food insecurity, climate change will put additional pressure on food systems. The changing environmental conditions, including more intense and lengthy droughts, extreme weather events, higher temperatures, and increased atmospheric CO_2 concentrations, affect the growth, yield, and nutritional content of several crops, including four staple crops (wheat, rice, maize, and soybean). In 2021, the duration of the growth season of these four crops followed a downward trend, exposing potential threats to crop yields. The average duration of the growing season for spring wheat, winter wheat, maize, soybean, and rice had decreased by 2.5%, 2.2%, 1.6%, 1.3% and 0.4%, respectively, compared to a 1981–2010 baseline (indicator 1.4). These impacts threaten the livelihoods of people depending on the agricultural sector and, ultimately, pose an acute menace to food security in the region.

The changing environmental conditions are also affecting the geographical distribution of infectious diseases. The region is endemic for dengue, which is responsible for a high burden of disease and frequent epidemic cycles across the region. The climate suitability for dengue transmission reached its highest level in recent years, with an increase of 35.3% in 2012–2021 compared to the 1951–1960 baseline (indicator 1.3). Estimated fitness for dengue transmission between 1951 and 2021 increased over time in all countries where the mosquito is found (except Argentina and Suriname). Adding to climate-related pressures, urbanisation, and mobility in countries such as Brazil and Peru have increased dengue spread to higher latitudes and less populated areas. Climate change can also lead to viral sharing among previously geographically isolated wildlife species, leading to cross-species transmission and disease emergence. Compounding the increase in dengue risk posed by climate changes, temperate Southern Cone countries are highly vulnerable to severe dengue outcomes, mainly driven by rapid urbanisation. Argentina and Uruguay experienced increased vulnerability between 1990 and 2019 (indicator 2.3).

South American countries must increase their preparedness to protect populations from the health impacts of the climate crisis

Understanding, assessing, and tracking the health impacts of climate change and health co-benefits of climate actions is critical for the development of adaptation plans and policies that can protect the health of SA populations from the increasing climate-related health hazards, and maximise their positive impact.

With the health risks of climate change rapidly increasing, countries should focus efforts on identifying their climate change-related health risks and develop adequate adaptation plans. At the sub-national level, 205 city municipalities conducted city-level climate change risk assessments (indicator 2.1.3), raising concerns about whether local-scale evidence, needs and within-country differences are being integrated into the National Adaptation Plans (NAPs).

Reflecting the insufficient planning for health adaptation, South American countries are not delivering adaptation responses proportionate to the rising risks their populations face. Adaptation actions, such as expanding urban green spaces (indicator 2.2.2), strengthening health systems (indicator 2.2.1), and building more resilient essential infrastructure, have the potential to reduce climate-related health impacts and promote health and wellbeing. However, of the 73 urban centres examined in 2021, 84% had very low or exceptionally low levels of green areas and only twelve (16%) had moderate levels of greenness. These findings reflect the limited progress in the implementation of an effective adaptation measure that can not only reduce exposure to health-threatening extremes of heat in urban areas, but also deliver major direct benefits through cleaner air, improved mental health and wellbeing from exposure to green space, and improved overall health outcomes from the provision of spaces for socialisation and recreation.

Enhancing health system capacity and resilience is essential, as the health risks associated with climate change increase and the population's healthcare needs rise. To enable this, efforts from government agencies must be focused on ensuring healthcare facilities have access to the essential services they need to provide adequate care, including, water and sanitation services, electricity supply and internet connectivity. Healthcare infrastructure must also be strengthened to cope with the increasing impacts of extreme weather events, and to be safe strongholds during climate-related emergencies. The capacity of the health system must be adjusted to be able to cope with the growing healthcare demand, and resources must be directed at empowering and training healthcare professionals to recognise, prevent, and treat the health impacts of climate change-related hazards. Finally, surveillance, early warning and early response systems must be implemented in collaboration with meteorological agencies and tailored to the local health risks, to inform the prevention and adequate response to climate change-related health hazards. Indeed, the call for universal coverage of early warning systems against extreme weather and climate change was enshrined in the agreement reached in the 2022 United Nations Climate Change Conference or Conference of the Parties of the UNFCCC (COP27). Yet only two countries in SA (Argentina and Brazil) report incorporating climate information for heat early warning systems in their health systems (indicator 2.2.1). The heat early warning system in Argentina was the only national early warning system that has been implemented and evaluated.

Strengthening health systems in SA to better prevent and respond to climate-related health risks will also deliver better overall health services, with overall gains to the health and wellbeing of SA populations. With the fragility of health systems exposed by the COVID-19 pandemic, strengthening local health services should be a priority in local governmental agendas.

SA must continue and accelerate efforts toward the race to zero-carbon transition

SA must continue and accelerate efforts to mitigate its GHG emissions, reduce land use change linked to deforestation, decarbonise its energy and transport system, and increase its use and production of renewable energies. Doing so will not only help the region meet its commitments under the Paris Agreement but will also deliver major health gains from improved air quality, reduced energy poverty, reduced inequities in access to transportation, and more active lifestyles.

While SA is responsible for only 6% of global GHG emissions, it must still join efforts to reduce global GHG emissions, and importantly to ensure it is not left behind in the global transformation towards a healthier, net zero emission human system. Emissions in SA are primarily linked to land use changes (24%), agriculture (28%) and energy production (39%). Given this, mitigation linked to land use and agricultural practices is particularly important, requires a long-term strategy, national and international incentive schemes, and strong governance and regulations, all of which are particularly challenging in SA countries (Panel 3). Climate change mitigation in the agricultural sector and in land use change linked to deforestation also hold the potential to deliver major simultaneous and immediate health benefits to local populations and promote healthier diets with additional benefits of reducing premature mortality from imbalanced diets. In SA, 23% of all deaths attributable to imbalanced diets have been linked to a high intake of red and processed meat and dairy products, the production of which is highly carbon intensive (mainly due to emissions associated with livestock feed production and ruminant enteric fermentation). Minimising red meat intake as per dietary guidelines would therefore not only help avert these deaths, but simultaneously lead to reduction in GHG emissions related to livestock rearing and the associated agricultural practices (indicator 3.4).

Turning to the energy sector, mitigation here can also provide substantial and immediate health co-benefits. The burning of fossil fuels not only contributes to increased GHG concentrations in the atmosphere but also leads to toxic levels of pollution in the air people breathe. In SA, exposure to harmful small particulate air pollution ($PM_{2.5}$) in the outdoor air resulted in 37,000 deaths in 2020 alone (indicator 3.2). The South American countries with the highest mortality rate attributable to exposure to $PM_{2.5}$ are Chile and Peru, with 230 and 176 deaths per million. The monetised costs of premature mortality due to air pollution in SA were equivalent to the average income of 2.9 million people (indicator 4.1.3).

Switching to clean fuels can also significantly reduce exposure to household air pollution (HAP) and diminish urban-rural health inequalities. Despite the almost universal access to electricity in South American homes, only half is generated from clean sources such as solar, wind or hydropower. In addition, big urban-rural differences exist, with 23% of the rural populations still relying exclusively on biomass fuels for cooking, exposing them to high levels of air pollutants inside their homes (indicator 3.1.1). The annual average of exposure of a rural household is 171 $\mu g/m^3$ [95% CI 159–183] of $PM_{2.5}$, 34 times higher than the World Health Organization (WHO) recommended annual 5 $\mu g/m^3$ threshold (indicator 3.1.2).

Decarbonising road transport could also deliver major benefits to the health of SA populations. Reducing fossil-fuel based road travel can help avert the over 10,100 deaths that were attributable to exposure to $PM_{2.5}$ air pollution coming from the transport sector in 2020 (indicator 3.2). Expanding the access and use of safe, affordable, and reliable public transport networks would not only reduce the use of fossil fuels but would also deliver major co-benefits from reducing the socioeconomic inequalities associated with transport access. In addition, promoting modal shift to active forms of travel by providing incentives and safe infrastructure can simultaneously deliver major physical and mental health benefits associated with increased physical activity.

Despite these potential health gains, South American countries have increased the per capita use of energy for road transport by 138% between 1971 and 2019. Specifically, countries like Paraguay, Ecuador, Bolivia, and Guyana have tripled their per capita energy use in road transport since the 1970s. This happened parallel to a rapid urbanisation process and increased regional car sales. Fossil fuels are still the primary energy source for road transport in SA, accounting for 84% of it, followed by biofuels (16%). While often promoted as a sustainable alternative, biofuels do lead to net carbon emissions (especially first-generation biofuels), their production often results in net emissions from land use change, and importantly their burning emits air pollutants such as $PM_{2.5}$ that harm human health. And while Chile and Ecuador are leading the road travel electrification in the region, even in these two countries less than 1% of the road energy sources comes from electricity. In the region, electricity accounts for only 0.04% of the energy used in road travel (indicator 3.3).

As the global energy crisis drives sharp increases in international energy prices, and as the rising inflation threatens people's capacity to afford clean energy, energy poverty in the region is likely to increase—and with it, the use of dirty fuels in people's homes. Rapid action to move away from fossil fuel use in the region and increase the local production of renewable, clean energy at all levels (i.e., individual, household, community, and society) would not only contribute to meeting the commitments countries laid out in the Paris Agreement, but would also deliver more resilient, stable, and sovereign energy systems for South American populations. This, in turn, would reduce the region's dependence on volatile international fossil fuel markets and geopolitical conflicts, help reduce energy poverty and its associated health impacts, and improve the quality of the air people across the region breathe.

Concerningly, despite the harms of the continued overdependence on fossil fuels to SA populations, countries in the region keep providing financial incentives for fossil fuel consumption, hampering the transition to clean, renewable energy sources. Considering all subsidies and carbon pricing instruments, the region still effectively subsidies fossil fuel consumption, to a total value that is on average equivalent to 10.5% of governmental health spending in the region (indicator 4.2). Currently, Venezuela, Ecuador, Bolivia, and Argentina net fossil fuel subsidies are equivalent to 85.6%, 29.2%, 23.5%, 15.4% respectively, of their health budgets. These net subsidies equivalents range between 3.5% and 4.8% for Brazil, Chile, and Colombia. In total, the six countries spent USD 27.9 billion on fossil fuel subsidies in 2021. Redirecting such spending towards subsidising renewable energies, and towards protecting vulnerable populations from the rising energy costs and the cost-of-living crisis, would not only promote the transition to a healthy, low-carbon future, but also help reduce inequalities and energy poverty.

South American countries require serious financial commitments to respond to the challenges imposed by climate change

Implementing climate change adaptation policies and actions for the health and wellbeing of populations is a no-regrets investment that requires the support of governments, with transparent financial commitments and concrete budget allocation.

As South American governments start to submit their second round or updated versions of their Nationally Determined Contributions (NDCs), eight of the 12 countries with submitted revised NDCs by 2021. The percentage of change in the number of mentions of health-related terms from the first to the second NDC was 130.4%. The countries with the greatest number of mentions were Venezuela, Paraguay, and Colombia (indicator 5.3). This reflects the awareness of the links between health and climate change and the prioritisation of the national climate agendas. However, many of these NDCs are high-level commitments that consolidate a country's intention–in some cases, not fully detailing the activities, indicators to monitor its progress, the institutional roles, and responsibilities and/or a budget for its implementation. Usually, this more detailed description is developed in NAPs, and sectoral NAPs–in the case of health–a NAP for Health (or HNAP). Despite the high-level recognition of the importance of having health-related activities in countries' NDCs, only Brazil has developed an HNAP up to 2021, while other countries–Argentina, Colombia, Chile, and Peru-report having them ready but not submitted or under development.

Despite the urgent need to protect the health of local populations from rapidly increasing health hazards, health adaptation is woefully underfunded in SA, with only 10% (USD 36 million) of approved adaptation-related funding dedicated to health in 2021 (indicator 2.2.3). However, the large sums of money allocated to subsidising fossil fuels show that funds are generally available, but they are not being allocated to activities that would enable a safe and healthy future.

Infrastructure and social spending needed to meet climate goals range between *"7% and 19% of gross domestic product (GDP) by 2030 (USD 470 billion to USD 1300 billion in 2030) depending on initial conditions and proposed economic and social targets"*.[†] Under this light, a just transition to a sustainable future requires enough funds to be made available to less industrialised countries, including many in SA. Less industrialised countries must be empowered to deliver a transition to zero-carbon, healthy, and resilient energy systems, and stronger, better prepared healthcare systems. In COP27, "developed" countries were urged to scale up their provision of climate finance, technology transfer and capacity-building to respond to the adaptation and mitigation needs of "developing" counterparts. The implementation of this ambition, to be progressed at COP28, is not only essential to deliver the goals of the Paris Agreement, but also to deliver better and more equitable global health.

The implementation of accelerated climate action requires support from key actors and sectors in society, including policy makers, scientists, the media, and the general public. Effectively communicating the science on the links between climate change and health is critical to changing public perceptions, generating public demand for action, and informing the implementation of evidence-based adaptation and mitigation policies that maximise health gains. Media coverage of the links between health and climate has been increasing in SA and reached its highest level in key newspapers from eight countries in SA in 2021 (Indicator 5.1). And while the health dimension of climate change remains understudied in the region, original research led by SA researchers has increased by more than 1000% since 2007. Yet, 94% of the health and climate change articles referred to climate impacts on health, while the number of articles regarding the effects of multisectoral action (health co-benefits and adaptation) on climate and health continues to be low (indicator 5.2). Research on the benefits of health -centred climate action is urgently needed in SA, to inform an evidence-based adaptation and mitigation response that maximises the benefits to local populations.

This inaugural report from LCSA focuses on (i) the immediate health threats posed by climate change in SA, (ii) the limited health adaptation plans developed in the region, (iii) our need to accelerate efforts towards the race to zero-carbon transition and (iv) the existing financial gap to address the burden of climate change on health in SA. Additionally, this report brings to light the need to foster regional efforts towards building resilient health systems and reducing the converging effect of inequality, poverty, and vulnerability in the face of climate change. Never has it been more important to realise the ambition of the Paris Agreement to limit the global average temperature rise to 1.5 °C and to dispense the financial resources necessary for effective climate response. In addition, such climate action could deliver immediate and substantial benefits, saving millions of lives each year by improving air quality, diet and physical activity and generating more resilient health systems. The LCSA calls on the governments and multiple stakeholders of the region to initiate and accelerate a coordinated response, and to define and undertake clear actions that address the challenges posed by climate change while ensuring healthy lives, clean environments, ecosystem services and wellbeing for all South American peoples.

Introduction

People are living through an unprecedented public health and environmental crisis due to anthropogenic climate change, which is undermining the foundations of good health, livelihoods, ecosystem services and human rights globally. To face these challenges, the Paris Agreement set out an ambitious commitment to reduce greenhouse gas (GHG) emissions and limit global warming to well below a global average surface temperature rise of 2 °C above pre-industrial levels, even aiming to limit temperature increases to 1.5 °C. To meet this target, urgent and effective action must be taken: reduce GHG emissions by 45% by 2030, phase out fossil fuel burning by the middle of the century and stop deforestation. However, current partner countries' Nationally Determined Contributions (NDCs) fall short of the necessary reductions to meet this pathway by 2030, with present policies putting the world on track to a global temperature rise of 2.7 °C.[1]

South America (SA) is a distinctive region rich in culture, ethnicity and in biological diversity. Its surface area corresponds to 87% of Latin America and the

[†]Paliza LMG, Hoffman B, Vogt-Schilb A. How Much Will It Cost to Achieve the Climate Goals in Latin America and the Caribbean? 2022; published online July 11. https://halshs.archives-ouvertes.fr/halshs-03720397/document.

Caribbean (LAC) and roughly to one-eight of the land surface of Earth. The region hosts most of the LAC population (66%) and of roughly 6% of the global population. South American countries are responsible for 6% of all GHG emissions globally, mainly stemming from their high dependence on fossil fuels for energy (39% of the total in the region), which in turn is responsible for a high burden of disease from the associated air pollution and energy poverty. Equally important are the emissions stemming from land use changes and agriculture (24% and 28%, respectively, of the total in SA).[2] Despite this relatively low regional GHG emission, SA's highly vulnerable population is already seeing their health strongly impacted by climate change. These impacts are further compounded by oftentimes overloaded and fragmented local health systems (Panel 2). SA is a region already burdened by high inequality, poverty, population growth, increasing urban population density, high rates of land use change, biodiversity loss, land degradation, and an increasing dependence of national and local economies on natural resources to produce globally required commodities, including fossil fuels.[3] Despite its wealth in renewable energy resources, the dependence on international energy markets makes SA particularly vulnerable to volatile fossil fuel markets, and the energy poverty that arises from international fluctuations in energy prices.

Furthermore, South American countries are particularly exposed and vulnerable to climate-related hazards. The increased frequency and intensity of extreme weather events in SA, such as floods, droughts, and heatwaves, are impacting its communities disproportionately. In 2018, large parts of Brazil experienced year-round droughts.[4] The rapidly rising temperatures are also putting the health of local populations at risk, and in 2019, the Argentine, Chilean and Uruguayan populations were considered the region's most vulnerable to heat.[5] The changing climate is also becoming increasingly suitable for diseases like dengue, which are of particular public health concern in the region. Indeed, driven mainly by the climate, increased movement of people and urbanisation,[6] the incidence of dengue saw a substantial rise over the past four decades in SA, with almost 16 million cases in 2011–2021.[7] Coupled with the cyclical ENSO, the region is projected to face more extreme challenges in a changing climate.[8] However, the severe consequences of these hazards on SA's economies, energy security and the health and wellbeing of millions of people are still insufficiently quantified and researched.

Concerningly, climate change is not the only challenge SA faces. In the past three years, converging global health and geopolitical crises have further exposed, and even exacerbated, the sizable socioeconomic disparities and global health inequities in the region. In particular, the COVID-19 pandemic has brought to light the insufficient policy response in the health sector -mainly due to poor governance, a lack of integrated health surveillance, response systems and universal health coverage. Meanwhile, Russia's invasion of Ukraine, which made fuel and food prices soar and the export of key commodities from the SA region to drop, revealed the interdependencies of SA not only with its neighbours, but also with distant countries. The resulting global energy and economic crisis have disproportionately affected SA, and further affected the regional socioeconomic conditions that good health depends on. With the converging energy, economic, geopolitical and health crisis compounding the impacts of climate change on the local populations, it has never been more urgent to reduce social and economic inequalities and strengthen the health systems and their response mechanisms–which are essential to enhance community resilience to climate change.

Important questions remain. Is the implementation of adaptation and mitigation measures to avert and minimise the health impacts of climate change being unrolled in an efficient and timely manner in SA? Are the potential health gains of climate action being maximised in the region? What are the barriers and limitations towards a just transition for SA? SA would see substantial benefits from a quick transition to renewable energy, reduced dependence on fossil fuels, greening of SA's ever-growing cities, and enhancing carbon sinks, mainly in the Amazon, the Andes wetlands, and the southern temperate forests, by curbing land use change and deforestation. As the world gets dangerously close to climate change-triggered tipping points, and as the committed temperature increase gets dangerously close to 1.5 °C, climate action in SA can no longer be delayed.

Increased multisectoral capacity for preparedness and response to climate-related health emergencies, strengthened climate governance, and effective implementation of mitigation and adaptation measures are urgently needed across all South American countries. A better understanding, monitoring, and quantifying of the health impacts of climate change and the health co-benefits of climate change mitigation and adaptation strategies is also essential to ensure the health gains of the transition to a low-carbon, resilient future is maximised.

Responding to this challenge, the *Lancet* Countdown South America (LCSA) exists as a regional centre of the *Lancet* Countdown. LCSA is an independent, multidisciplinary collaboration that tracks the links between public health and climate change in SA. It brings together 21 academic institutions and UN agencies from the region, mirroring the global *Lancet* Countdown's methodologies and five key domains: health hazards, exposures, and impacts; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement.[1,9]

This is the first report of its kind in which the collaboration tracks 25 health and climate change indicators (Table 1) chosen according to their regional

Section	Indicator	
Health hazards, exposures, and impacts	1.1 Health and heat	1.1.1 Exposure of Vulnerable Populations to Heatwaves
		1.1.2 Heat-related mortality
	1.2 Wildfires	
	1.3 Climate suitability for infectious disease transmission	
	1.4 Food security and undernutrition	
Adaptation, planning, and resilience for health	2.1: Assessment and planning of health adaptation	2.1.1 National assessments of climate change impacts, vulnerability and adaptation plans
		2.1.2 National adaptation plans for health
		2.1.3 City-level climate change risk assessments
	2.2: Enabling conditions, adaptation delivery, and implementation	2.2.1 Climate information for health
		2.2.2 Urban green space
		2.2.3 Health adaptation-related funding
	2.3: Vulnerability to mosquito-borne diseases	
Mitigation actions and health co-benefits	3.1 Clean household energy	3.1.1: Access to clean fuels and technologies
		3.1.2: Exposure to household air pollution
	3.2 Premature mortality from ambient air pollution by sector	
	3.3 Sustainable and healthy transport	
	3.4 Diet and health co-benefits	
Economics and finance	4.1: The Economic impact of climate change and its mitigation	4.1.1 Costs of heat-related mortality
		4.1.2 Loss of earnings from heat-related labour capacity reduction
		4.1.3 Costs of the health impacts of air pollution
	4.2: Net value of fossil fuel subsidies and carbon prices	
Public and political engagement	5.1 Media coverage of health and climate change	
	5.2 Scientific engagement in health and climate change	
	5.3 Government engagement in health and climate change	
	5.4 Corporate sector engagement in health and climate change	

***Table 1:* The indicators of the 2022 South America report of the Lancet Countdown.**

relevance and data availability for 12 South American countries.[‡] The report draws from the data and methods used for the 2022 global *Lancet* Countdown report[1] and other available data sources.[10,11] The LCSA has taken steps to ensure that it has the expertise, data, and representation of the entire South American region to create a monitoring system that fits the region's specific singularities. The LCSA has partnered with 11 South and Central American universities, four international and, at the same time, collaborates closely with UN institutions and other regional organisations that share the goal of bringing evidence to light and triggering health and climate change action. The findings and conclusions of this inaugural report are the cumulative result of the LCSA's collaborative work during the past year and represent the consensus of experts in environment, energy, food, transport, economy, social and political scientists, public health professionals, and medical doctors across the region.

Future work will fill critical research gaps by proposing and tracking new and relevant indicators for the South American region. LCSA will continue to focus on supporting regional and national efforts, building capacity for communications and engagement, guiding a data-driven policy dialogue with key stakeholders and policymakers, and further improving existing indicators. To this end, the ongoing growth of the LCSA depends on the dedication of the global *Lancet* Countdown team, the composite of experts and local partners, the continued support from the Wellcome Trust, and the time and effort that the academic institutions of the collaboration are willing to give to this initiative.

Section 1: health hazards, exposures, and impacts

Climate change is a global phenomenon, but its impacts are felt unequally around the world. In SA, over the past decades, mean ambient temperature has increased across the entire region, precipitation has decreased below normal in several locations, glaciers have rapidly retreated in the Andes region, and sea level has increased in the Pacific and Atlantic coastlines.[12] The

[‡]The 12 countries considered in this report are: Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, Guyana, Paraguay, Peru, Uruguay, Venezuela, and Suriname. French Guiana has not been considered in this report, as it is an overseas department of France.

increase in climate hazards compounds with the El Niño-Southern Oscillation (ENSO) and with substantial population exposure and social vulnerabilities, to result in direct, indirect, multiple, and cascading effects that threaten the health and wellbeing of local populations. Heatwaves, wildfires, lower crop yields, climate change-driven threats to water and food security, and extended climate suitability for climate-sensitive infectious diseases, such as dengue, are only a few of many potential quantifiable and increasing climate-related hazards that have impact on population health.

Understanding the health hazards, population exposure and vulnerability, and the resulting health impacts of climate change, is critical for guiding climate policies that can improve population health and wellbeing. Based on the 2022 global *Lancet* Countdown report, this section tracks five indicators on the health hazards, exposures, and impacts of climate change of relevance to SA. First, it presents regional information on the exposure of vulnerable populations to heatwaves (indicator 1.1.1), heat-related deaths among people above 65 years old (indicator 1.1.2), and population exposure to very high to extreme high fire risk (indicator 1.2). Next, it explores the changing climate suitability for dengue transmission, an important vector-borne disease in the region (indicator 1.3), providing information that can help inform public health interventions. The last indicator monitors the impact of climate change on the agricultural cycles and potential productivity of different crops, providing an assessment of the potential risk to food insecurity in South American communities (indicator 1.4).

Health and heat

Indicator 1.1.1: exposure of vulnerable populations to heatwaves—headline finding: in the 2012–2021 period, on average, children younger than 1 year old were affected by 2.35 million more person-days of heatwave exposure each year, and adults older than 65 years were affected by 12.3 million more person-days of heatwave exposure compared to the 1986–2005 average

Increasing temperature has been recorded in every country in SA over time, with remarkable anomalies ranging from 1 °C to 2 °C in several parts of Brazil, Colombia, Chile and Argentina in 2021 relative to 1981–2010.[12] Heatwaves in the region were exceptionally intense and long in some countries, including Argentina, Brazil, Chile, Paraguay, and Peru.[12] This warming has led to higher population exposure to high and sustained ambient temperature, including heatwaves, which have been globally associated with health risks, especially among young and older people.[13]

Drawing on the 2022 global *Lancet* Countdown report, this indicator uses data from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 data,[14] NASA Gridded Population of the World version 4,[15] and United Nation World Population Prospects data,[16] to estimate the absolute difference in the number of days children younger than 1 year old and people older than 65 years old were exposed to life-threatening heatwave events (considered as 2 or more days where both the minimum and maximum temperatures were above the 95th percentile of the local climatology), compared to the 1986–2005 baseline.[17,18] The absolute number of person-days was obtained by subtracting the yearly estimates and the 1986–2005 average.[1]

Between 2010 and 2020, the number of person-days of heatwave exposure in almost all South American countries was consistently and substantially above the 1986–2005 baseline. Although the exposure to changes in the number of heatwaves was relatively low in 2021, that was not the trend from 2012 to 2021 (Fig. 1). In this 10-year period, children younger than 1 year old were affected, on average, by 2.35 million more person-days of heatwave exposure each year, and adults older than 65 years old were affected, on average, by 12.3 million more person-days of heatwave exposure each year compared to the reference period (1986–2005).

The magnitude of the changes in Fig. 1 is determined both by an increase in the number and length of heatwave events, as well as by changes in population size, age composition, and the latitude and geographical location of the population.[18,19] Noticeable high values in 2015, 2016, 2019, and 2020 were mostly driven by more frequent or lengthy heatwave events rather than unusual or sudden population changes. Increases in 1983 and 1998 coincided with the two significant El Niño events.[20]

Indicator 1.1.2: heat-related mortality—headline finding: the estimated number of heat-related deaths has increased, on average, by 160% in the 2017–2021 period compared to the 2000–2004 period

The exposure to extreme heat along with personal and social vulnerabilities increases the risk of death from all causes, particularly cardiovascular, cerebrovascular, and respiratory conditions amongst vulnerable people older than 65 years old.[21,22]

This indicator draws on data from the 2022 global *Lancet* Countdown report and estimates heat-attributable deaths of people older than 65 years old between 2000 and 2021,[1] following exposure-response functions proposed by Honda et al.[23] and by using data from ECMWF ERA5,[14] the NASA Gridded Population of the World version 4,[15] and the United Nations World Population Prospects.[24]

In SA, the estimated number of heat-related deaths has followed an upward trend between 2000 and 2021, with Brazil, Argentina, Colombia, and Venezuela the most affected in terms of total attributable deaths. The countries with the highest relative change are Ecuador (1477%), Guyana (328%), and Chile (225%), while the countries with the lowest increase are Paraguay (143.2%), Argentina (85.2%), and Uruguay (37.4%).

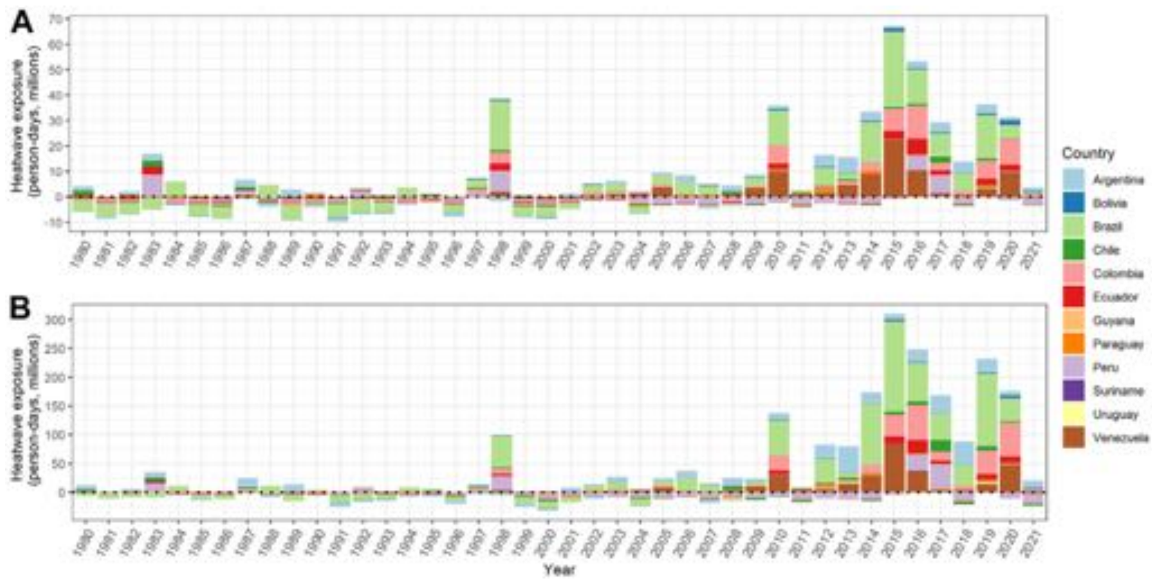

Fig. 1: Total exposure to change in the number of heatwave days relative to the 10-year average 1986–2005 baseline of **(A)** People younger than 1 year old and **(B)** people older than 65 years old. The dotted line represents no change.

2020 was one of the three years with the most heat-related deaths for all countries, and seven out of 12 countries reached historical records. This record was partially triggered by the extended and intense heatwave in SA[25,26] and by the increase of the exposure in vulnerable populations (indicator 1.1.1). Interannual variations are expected to happen and might be driven by climatic factors and rapid-onset hazards, such as the COVID-19 pandemic.

Indicator 1.2 wildfires—headline finding: exposure of South American populations to very high or extremely high wildfire danger has increased in nine out of 12 countries, with an average increase of seven more days of exposure per person each year in 2018–2021 (35% of change), compared to the 2001–2004 baseline

The analysis of wildfires in SA is complex. The region combines unique and diverse biomes, with wildfires being an essential part of ecosystem dynamics, such as in the Brazilian Cerrado. However, as a biome, the Amazon rainforest, which is not adapted to exposure to fire during the life cycle of its plant species, has relatively low resilience to wildfires. This is becoming aggravated by land use change and deforestation.[27] Although most wildfires in SA originated from deliberate human activities, climatic changes can make climatological conditions more suitable for their start and spread, including through high ambient temperature, reduced precipitation, and humidity, making wildfires more frequent, extensive, and challenging to control.[28] This combination of factors results in amplified damage and more negative impacts on population health and wellbeing.

Wildfires pose a multilevel and systemic risk for human health and wellbeing through several pathways: (i) wildfires can cause direct physical harm or death[29]; (ii) smoke inhalation from wildfires poses several acute and chronic health threats, including increased morbidity and mortality[30]; (iii) the loss of assets and loved ones has an impact on mental health (Panel 1). In addition, wildfires can exacerbate environmental degradation and climate change, therefore worsening health risks. Characterising the climatological fire risk in SA, particularly in the Amazon, would help understand the phenomenon and inform potential adaptation and mitigation actions to reduce health hazards.

This indicator draws on data from the 2022 global *Lancet* Countdown report, to track population exposure to very high and extremely high fire danger based on meteorological conditions favourable to the start, spread, and sustainability of fires. Data from the Fire Danger Index (FDI) was obtained from the Copernicus Emergency Management Service for the European Forest Fire Information System (EFFIS)[31] and combined with the NASA Gridded Population of the World version 4 dataset,[15] and the United Nation World Population Prospects data.[24] To focus on wildfires as opposed to urban fires, urban areas with population density ≥400 persons/km^2 are excluded.

In the nine out of the 12 countries that saw an increase in very high or extremely high wildfire danger, people experienced an average of 7 more exposure days annually, as compared to the 2001–2004 baseline. However, there were important differences in the number of exposure days across countries. Uruguay, Paraguay saw an increase of 3-4 exposure days, vs Argentina and Chile 14–20 days of exposure per year (Table 2).

Wildfires in SA, especially in Amazon, the Pantanal, and El Chaco, result in major forest and biodiversity loss,[32,33] because SA holds 21% of the world's remaining forests. Wildfires driven by deforestation and degradation processes have a double impact in the concentration of GHG emissions in the atmosphere as they decrease the ability of natural systems to act as GHG sinks[34]; and negative synergies between deforestation, climate change, and wildfires are leading to a non-reversible tipping point in the Amazon ecosystem to become a non-forest ecosystem with 20–25% deforestation, causing a massive effect in its hydrological cycle, fundamental for human wellbeing and agriculture in Brazil and adjacent South American countries.[34]

Indicator 1.3 climate suitability for infectious disease transmission—headline finding: climate-related suitability for dengue transmission has steadily increased in SA since 1951, rising by 35.3% in 2012–2021 compared to the 1951–1960 baseline

Climate change affects the transmission of vector-borne diseases, such as dengue, via increased temperatures, precipitation, extreme weather events, and other global climate variability phenomena such as ENSO. This is particularly important for highly endemic regions such as SA. This indicator focuses on monitoring the changing climatic suitability for the transmission of dengue, an infectious disease which has had a substantial rise in its incidence and severity during the last 30 years in SA.[35,36]

This indicator draws from the 2022 global *Lancet* Countdown report and tracks the climate suitability for dengue transmission by estimating its basic reproduction number (R_0) as a function of the vectorial capacity and abundance, and influenced by rainfall, temperature, and human population density. It focuses exclusively on transmission by *Ae. aegypti*, the primary dengue vector in the region, as the R_0 estimates for *Ae. aegypti* and *Ae. albopictus* are strongly correlated (>80%).

The estimated suitability for dengue transmission across 1951–2021 increased over time in all countries where the mosquito is found (except for Argentina and Suriname) (Fig. 2). On average, the R_0 in the region increased 0.53% annually, with the largest increases (>0.5%) in six Amazonian countries, some with highly linear yearly correlations (Determination coefficient R2 >50%). There were very low increases in Guyana, Paraguay, and Uruguay (0.17%–0.35% per year), and no significant linear trends in Suriname and Argentina.

The largest R_0 relative mean increases took place in the 1971–1980, 1981–1990 and 1991–2000 decades compared to the 1951–1960 baseline: 9.1%, 9.9% and 4.9%, respectively.[37] There were smaller (2.4–2.6%) increases in the two following decades. In 2012–2021, SA reached its highest climate suitability to dengue, rising by 35.7% compared to the 1951–1960 baseline, and then remained at a very high level in 2021. All countries, except Chile, showed important (>0.25) inter-annual R_0 variability at least once over consecutive years. Six countries had inter-annual changes >0.5, and the highest variability was observed in Peru and Ecuador, coinciding with El Niño years -the warmer phase of ENSO.

The sustained increase of dengue climate-related suitability until the 1990s is likely one of the drivers of the rapid expansion of dengue across SA,[35] with urbanisation and population movement also having strong influences.[37] Sizeable epidemics of dengue and the emergence of new *Aedes*-transmitted arboviruses have been repeatedly observed since. Understanding the lack of further suitability increases in the last 20 years in SA will help evaluating if more specific indicators are needed.

Country	2001–2004	2018–2021	Difference in days	% of change
Argentina	22.9	37.3	14.4	0.6
Bolivia (Plurinational State of)	23.1	30.8	7.6	0.3
Brazil	33.5	39.1	5.7	0.2
Chile	38.3	59.5	21.2	0.6
Colombia	10.6	12.3	1.7	0.2
Ecuador	0.9	0.7	−0.2	−0.2
Guyana	1.2	0.8	−0.4	−0.3
Suriname	0.4	0.1	−0.2	−0.6
Paraguay	4.2	8.7	4.5	1.1
Peru	7.3	10.6	3.3	0.5
Uruguay	0.7	3.9	3.3	5.0
Venezuela, Bolivarian Republic of	40.1	41.4	1.4	0.0

Table 2: **Population exposure to very high wildfire danger comparing 2018–2021 to the 2001–2004 baseline.**

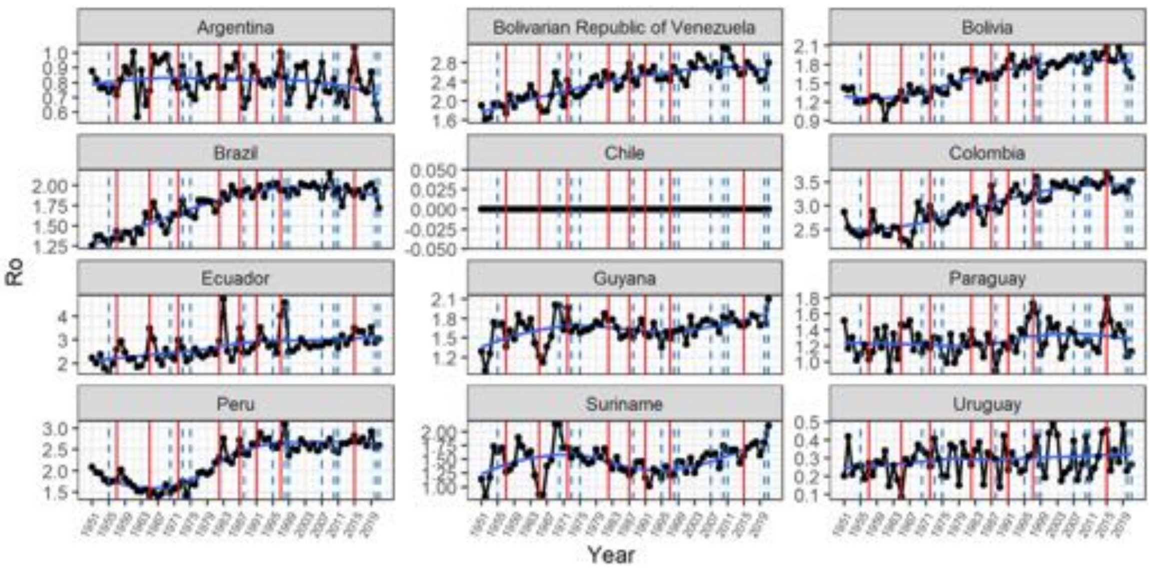

Fig. 2: Estimated R_0 for dengue (*Ae. aegypti*) by country in SA, from 1951 to 2021. Vertical lines in dashed light blue represent La Niña years and solid red lines represent El Niño years. The blue line represents a smooth local regression over time.

Indicator 1.4 food security and undernutrition—headline finding: on average, in 2021, the estimated duration of the growing season for spring wheat, winter wheat, maize, soybean and rice had decreased by 2.5%, 2.2%, 1.6%, 1.3% and 0.4%, respectively, relative to the 1981–2010 period

Changes in the climate affect the growth, yield, and nutritional content of several crops, including wheat, rice, maize, and soybean,[38] increasing the risk of food insecurity and its consequences on human health and wellbeing. Higher ambient temperatures during the crop growing season might shorten the time taken for crops to reach maturity, threatening crop growth and yield. In SA, where agriculture is a key sector (either for exports or internal consumption), tracking changes in potential crop yield is critical, as it can impact on economic and social development, food security, and human nutrition.

After remaining virtually unchanged for five years, world hunger increased in 2020. That year, the prevalence of undernutrition increased by 1.5 percentage points to 9.9% increasing the difficulties of achieving the second Sustainable Development Goal (Zero Hunger by 2030).[39] Populations in SA are highly vulnerable to food insecurity, and in 2020, 168.7 million people in SA suffered from moderate and severe food insecurity, Concerningly, the number of people suffering from food insecurity increased by 40 million in 2021, affecting more women than men.[40]

This indicator draws on data from the 2022 global *Lancet* Countdown report to estimate the reduction in crop growth duration, as a proxy for change in potential crop yield, and therefore for potential risks to agriculture and food security.

Crop growth duration is defined as the time taken in a year for crops to reach the accumulated temperature total needed to reach maturity, as defined in the reference period (1981–2010). In SA, crop growth duration has followed a downward trend for all crops since 1981. In 2021, the average duration of the growing season relative to the 1981–2010 period, decreased by 2.5% for spring wheat, 2.2% for winter wheat, 0.4% for rice, 1.6% for maize, and 1.3% for soybean (Fig. 3 and see Supplementary Material pp.1–4 for spring wheat, soybean, and rice figures). However, there are important differences between countries and the exact change depends upon the location and crop.

SA is currently experiencing a critical juncture, with a significant increase in food insecurity exacerbated by climate variability and extremes, conflict, economic downturns, and recessions, recently exacerbated by the COVID-19 pandemic. Considering these challenges, data collection on food insecurity is urgently needed, particularly to enable the development of more detailed indicators, and to help identify and characterise vulnerable populations. This can be a valuable tool to increase the knowledge about the relationship between food production, food insecurity, food nutritional potential, and the effects on human health and wellbeing, such as nutritional deficiencies, overweight, chronic diseases, and psychosocial consequences.

Conclusion

The evidence presented in this section shows that climate change is already threatening the health and wellbeing of South American populations. Increasing ambient temperature and heatwave events pose high risks to the health of the most vulnerable people,

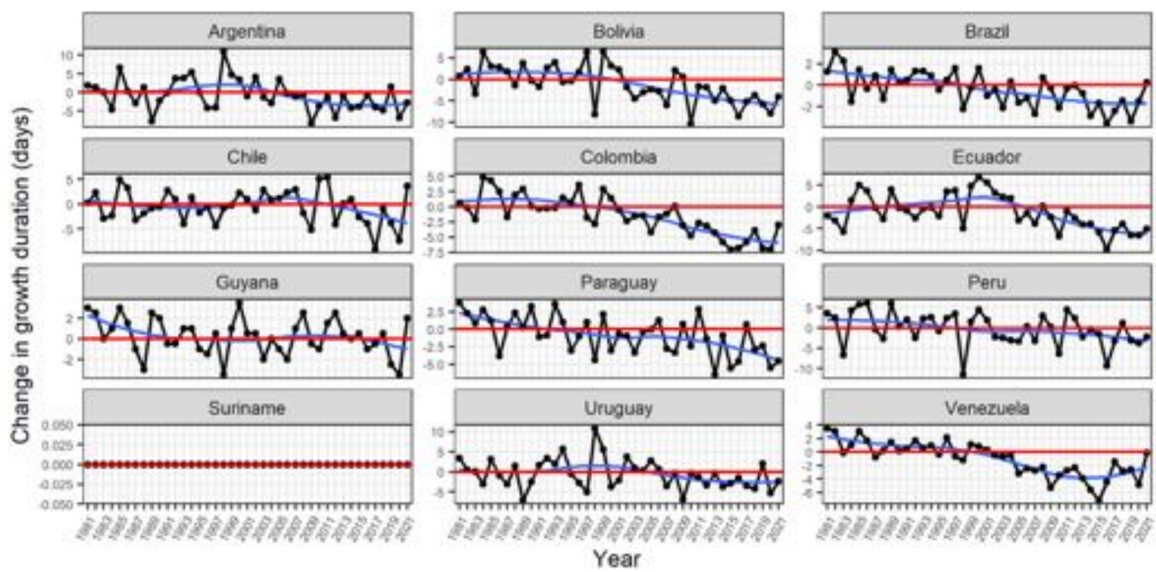

Fig. 3: Change in maize growth duration relative to the 1981–2010 average by country. The red line represents no change. The black line represents the annual area-weighted change in maize growth duration. The blue line represents a smoothing trend over time.

resulting in a rise in heat-related mortality. Importantly, much of this increase in mortality could today still be prevented through adequate adaptation measures. Increased exposure to days of high or extremely high meteorological fire danger is putting people at risk of life-threatening injuries, respiratory disease, and corneal injury from exposure to wildfire smoke, while the loss of infrastructure, disruption of essential services, and additional environmental degradation can have indirect health harms. Simultaneously, the climate-related suitability to dengue fever in the last decade has increased in key endemic regions, and severe dengue epidemics have been observed in recent years. Finally, high ambient temperatures are threatening crop yields, which might lead to negative effects in the agriculture sector, food security, and human nutrition. The ecological mega-diversity of SA and the special influence of cyclical climate variability lead to unique sub-regional scenarios dealing with very different climatic health hazards. Urgent adaptation and mitigation policies are critical to preventing the health risks of climate change to increase beyond our capacity to adapt and prevent the most extreme impacts to the health of local populations.

Panel 1: Mental health and climate change.

Climate change is eroding the social, economic, and environmental determinants for psychosocial wellbeing, and leading to multiple, interrelated, and wide-ranging mental health impacts.[41] These impacts vary from common mental disorders[42–44] to severe mental illnesses[45] and suicide,[46–48] and pose a greater threat to underserved populations[49–55] in the backdrop of historical social inequities. The burden that mental disorders have in the Latin American region is substantial, and frequently overlooked. e.g., The measured age-standardise disability-adjusted life-years (DALYS) associated to mental ill health from 1990 to 2019 in tropical Latin America was one of the highest worldwide[56]; the regional treatment gap for severe mental disorders have been estimated in 74.7% and 80% among indigenous groups[57]; (which accounts to 8% of the Latin American region' population).[58]

Estimates showed that only about 1 in 4 persons with any 12-month mental disorder in SA had received any kind of treatment.[59] Climate change threatens to further act as an amplifier of these existing mental health risks and interrupt the avenues for mental health and psychosocial support.[55] Those affected by structural and long-dating inequities and marginalised groups (e.g., indigenous population, women, and impoverished groups, among others) are most at risk for climate-related mental health impacts.

Despite the increase in the social, political, and environmental drivers of ill-mental health, and although public and political attention to the mental health impacts of climate change is increasing,[5,10,60] the understanding of the links between climate change and mental health is still limited. Data and indicators on mental health and climate change in Latin America and SA specifically, are particularly scarce. Lack of awareness, stigma, and misconceptions also impair the accessibility and registry of mental health data.[61–63] An added complexity concerns the different timings, severity, and persistence of exposures, including regional availability of research (indicator 5.2) and data on mental health impacts.[64,65] There is an urgent need to develop and track reliable global and regional indicators. These could focus on the effect that extreme weather events and heatwaves have on common mental disorders (e.g., depression, anxiety) and reported suicides across publicly available national level datasets.

Section 2: adaptation, planning, and resilience for health

With the health hazards and impacts of climate change rapidly increasing and temperatures bound to continue to rise even under the most ambitious climate change mitigation scenarios,[66] rapid, targeted, and efficient adaptation is essential to prevent the most extreme health impacts.

This is particularly important in SA, where inequalities, limited resources, and relatively weak health and health-relevant systems make local populations particularly vulnerable to climate change-related health hazards. While the region has experienced improvements in health systems and infrastructure over the past decades, reducing rates of mortality and morbidity,[67] much is yet to be done in building climate resilience to local health systems. Moreover, the COVID-19 pandemic triggered social and economic crises, leading to a rise in poverty and social inequalities,[68] presenting additional challenges for the health response to climate change. Importantly, climate change adaptation actions, such as expanding urban green spaces, strengthening health systems, and building more resilient essential infrastructure, not only have the potential to minimise climate-related health impacts, but can also offer broader benefits to the health and wellbeing of populations in SA.

This section reports on six indicators related to climate change adaptation, including national and city-level plans and assessments (indicators 2.1.1–2.1.3), climate-health information systems (indicator 2.2.1), urban greenspace (indicator 2.2.2), health adaptation funding (indicator 2.2.3), and vulnerability to mosquito-borne diseases (indicator 2.3). In addition, Panel 2 describes the importance of adopting indicators to track the resilience of health systems in the region.

Assessment and planning of health adaptation

Indicator 2.1.1: national assessments of climate change impacts, vulnerability and adaptation plans—headline finding: up to October 2021, Brazil was the only country in SA that reported having completed a climate change and health vulnerability and adaptation assessment

Climate change impacts and risks are becoming increasingly complex and more challenging to manage, which adds to the overall risk they pose across sectors. The level of risk will depend on the vulnerability, exposure, level of socioeconomic development, and adaptation measures of each country, making it urgent for countries to develop effective climate change adaptation measures targeting specific risks that contribute to health outcomes. The SA region has made progress as the countries adhere to the Paris Agreement, Cancun Adaptation Framework,[69,70] and regional health and climate agreements adopted by the Andean Community and Mercosur countries. As vulnerable people and systems are disproportionately affected, national climate change risk assessments can assist decision-makers in allocating human and financial resources more effectively, prioritising those who bear the biggest burden.[71–74]

This indicator monitors self-reported data countries, in which health sector representatives report on the state of national climate change health vulnerability assessments. It uses data from the 2021 WHO Health and Climate Change Global Survey,[10] which has responses from 91 governments, including nine countries from the South American region.

Brazil was the only country that reported having conducted a climate change and health vulnerability and adaptation assessment, and that it was completed in 2020. Brazilian authorities reported that results of the latest assessment informed the development of a new health policy or the revision of an existing one but did not influence the allocation of human or financial resources within the ministry of health to address health risks of climate change. Argentina and Peru reported having assessments under development. Bolivia, Colombia, Guyana, Suriname, and Uruguay informed they have not conducted an assessment, and data for Paraguay is unknown. Chile, Ecuador, and Venezuela did not participate in the survey. Additional review of national and regional documents on adaptation showed that Argentina developed a climate change and health assessment in 2019.[75]

Indicator 2.1.2: national adaptation plans for health—headline finding: up to 2021, Brazil was the only country in SA that self-reported having a national health and climate change strategy or plan in place

To protect their populations from the worst health impacts of climate change, every country will need to define how to integrate climate change adaptation and mitigation measures with health co-benefits in specific public health programmes within the health sector development plans. National Adaptation Plans for Health (HNAPs) can provide clear ministerial mandates for coordination, implementation, monitoring and evaluation, where roles and responsibilities are properly delimited, and which guide the allocation of adequate human and financial resources. Following these plans, the health sector can set the foundation for the broader climate-resilience-building process across other sectors.[76]

The indicator tracks the development of national health and climate change strategies and plans, and the barriers to implementation. The data comes from the 2021 WHO Health and Climate Change Global Survey,[10] which provides self-reported data on health sector responses to climate change from 91 governments. Nine out of 12 countries from SA completed the survey. Chile, Ecuador, and Venezuela did not participate.

Brazil was the only country that reported having developed a HNAP up to 2020. However, Brazil's level of implementation was moderate, with action reported against only on some of the plan/strategy priorities. Argentina, Colombia, and Peru reported having plans under development. Bolivia, Guyana, Suriname, and Uruguay do not have an HNAP in place, and data for Paraguay is unknown.

An additional review of national and regional documents on adaptation was performed to complement the information countries provided through the WHO's survey. This showed that Chile already had adopted an HNAP in 2016,[77] and Argentina adopted its first action plan on health and climate change in 2019.[78] The development of an HNAP is also underway in Uruguay and is anticipated for 2025.[79]

Despite advances in the region, South American countries continue to lag in the creation of HNAPs, limiting the ability of governments to adequately address health issues related to climate change, procure funding, and identify solutions to strengthen the resilience of health systems.[80] In future iterations of this indicator, in addition to tracking HNAPs, this indicator will track the health mentions in the national adaptation plans by sector to monitor if health is being including in the adaptation planning in SA.

Indicator 2.1.3: city-level climate change risk assessments—headline finding: in 2021, two-thirds (65.3%) of 205 SA cities surveyed had either already completed or were in the process of undertaking climate change risk and vulnerability assessments

Four-fifths of the South American population currently live in urban areas.[76] According to WHO, unplanned urbanisation led to new health challenges, such as pollution, increased vulnerability to climate hazards, inequity and even led to cities becoming epicentres of disease transmission. Climate change risk and vulnerability assessments can inform city-level adaptation measures to address environmental issues, reduce the harmful impacts of climate change, build resilient societies, and improve overall quality of life. This indicator uses the CDP Annual Cities Survey which reports on cities that voluntarily have conducted climate change city-level risk and vulnerability assessments.

In 2021, 205 city municipalities from ten countries in the SA region voluntarily completed the survey. Guyana and Suriname are the only countries with no assessments. Of the 205 SA cities responding to the survey, only 107 (52.1%) had a complete climate change city-level risk and vulnerability assessment; 27 (13.1%) had them in progress and 47 (22.9%) intended to undertake them in the next two years. The countries with the highest number of city municipalities responding to this assessment were Argentina, Brazil, and Colombia. Countries with one completed assessment included Uruguay, Venezuela, and Paraguay. The main hazards identified in the CDP survey vary by city municipality. The hazards most frequently identified by city municipalities in Brazil and Argentina were extreme precipitation and flooding as the main hazards, cities in Peru most frequently identified water scarcity and extreme temperatures as a hazard of concern, while those in Chile and Colombia identified wildfires. Cities in a few countries (Colombia and Brazil) identified mass movement or climate migration as potential climate hazards.

This indicator suggests that promising advances in climate change assessments are occurring in city municipalities. Assessments are an important early step towards effective adaptation to climate change. This indicator will continue to evolve to include information on specific risks across the region, allowing city-level decision-makers to identify common hazards and plan accordingly.

Future iterations of the indicator will explore implementing planned adaptation solutions to the identified risks and vulnerabilities. There is a need for more municipalities to develop climate change adaptation plans that take health impacts into account based on evidence of climate change risks and vulnerabilities. The results will also be analysed and presented based on a percentage of the total number of municipalities of each country to provide comparable representations on the assessments undertaken in countries with different numbers of urban centres.

Enabling conditions, adaptation delivery and implementation

Indicator 2.2.1: climate information for health—headline finding: in 2021, only two countries of SA reported that their health systems incorporated meteorological information. The heat early warning system in Argentina was the only national early warning system that has been implemented and evaluated

With climate-related health hazards on the rise, the provision of climate services tailored to the health sector is essential to the development of early warning systems to climate-related health hazards, and climate-related risk surveillance. These tools can support public health decision-makers in the implementation of early interventions and response systems that can reduce or prevent the health impacts of climate change on local populations.[10]

This indicator monitors the extent to which health surveillance systems and early warning systems (EWS) incorporate climate information, based on the results of the WHO Health and Climate Change Global Survey, a global survey of health focal points conducted in 2021.[10] Data was reported by nine SA countries (no data for Chile, Ecuador, and Venezuela).

Argentina and Brazil were the only countries that reported that their health systems incorporated meteorological information. Argentina was the only country to report a health EWS already in place. This EWS was based on epidemiological information and was evaluated.[81–83] Initially set up a city-level for Buenos Aires, it was later implemented at the national level.

Beyond EWS, other efforts to implement climate services for health in SA include climate and health observatories, integrated climate and health surveillance systems, and vulnerability maps.[3] Examples from the region include an experimental monitoring and forecasting system for environmental suitability of *Aedes*-borne disease transmission in northern SA,[84] heatwave and extreme cold monitoring and alert systems in Argentina,[85] and a climate and health observatory in Brazil.[86] Advances in surveillance systems, modelling, and computing tools in the last decade have increased the availability of digital climate and health records and the accuracy of predictions of climate-related health risks. In some places with scarce climate information, satellite imagery can help to fill data gaps.[87,88] However, as climate change-related threats increase, the region will need to invest more efforts in implementing climate services for health, to minimise the adverse impacts on local populations.

Indicator 2.2.2 urban green space—headline finding: in SA, 84% of urban centres were classified as having low, very low, or exceptionally low greenspace coverage in 2021. No urban centres had levels of greenspace classified as high or above. However, urban centres classified as having moderate greenspace increased by 9.6% since 2010

Preserving and expanding greenspace is an important climate adaptation and mitigation strategy which has been adopted by several cities across the world. Increasing greenspace in urban areas can additionally provide substantial health co-benefits, as it is linked with improved human physical and mental health, and the reduction of general and cause-specific mortality and morbidity.[89] Although the mechanisms of such beneficial effects are still not completely understood, it has been hypothesised that it could be mediated by the effect of greenspaces in reducing air and noise pollution, their local cooling effect, as well as by urban greenspaces providing appropriate spaces for physical activity and social interaction, all of which has positive impacts in physical and mental health. But despite their recognized health and climate benefits, there are still enormous disparities in the quantity, accessibility, and quality of greenspace within and between cities and countries, with the most vulnerable populations often having less access to greenspace,[90,91] as demonstrated in Argentina[92] and Peru.

A sample of large urban areas in 12 countries in SA was examined, and the vegetation coverage was estimated using the satellite-based normalised difference vegetation index (NDVI).[1] Population-weighted NDVI was calculated as an estimate of exposure to greenspace. The level of Greenness was defined as “exceptionally low” (Population-Weighted Peak NDVI <0.20); “very low” (0.20–0.29); “low” (0.30–0.39); “moderate” (0.40–0.49); “high” (0.50–0.59), “very high” (0.60–0.69) and “exceptionally high” (≥0.70). The analysis was performed for the years 2010 and 2021.

Of the 73 urban centres examined, only 12 (16%) presented moderate levels of greenspace in 2021 (i.e., NDVI ≥0.40 and <0.49), representing an increase of 9.6% since 2010. The mean urban population weighted peak NDVI in SA was 0.31 and the maximum value observed was 0.45. The overall mean exposure to green areas increased by around 12% between 2010 and 2021, although about 18% of urban centres experienced a decrease in their green areas during the same period (Fig. 4). Most countries presented an increase in mean levels of urban greenspace between 2010 and 2021 but Paraguay and Chile showed a decrease in the period.

The availability of green spaces in urban areas in SA is still amongst the lowest levels in the world, and the growth of these areas in recent years has been quite modest.[91] Increasing urban greenspace in the region is an important and low-cost measure that would deliver major health benefits to local populations.

Indicator 2.2.3: health adaptation-related funding—headline finding: health adaptation is woefully underfunded in SA, with only 10% (US$36 million) of approved adaptation-related funding dedicated to health adaptation in 2021

Implementing climate change adaptation policies and actions for the health and wellbeing of populations requires transparent financial commitments with budget allocation and securing and facilitating access to international funds.[60] Given the present and expected future impacts of climate change in the region, and the economic situation of most SA countries, access to international funding for climate change adaptation, particularly with a focus on health outcomes, is an urgent need in the region. This indicator tracks overall and health-specific spending in adaptation and cross-cutting projects.

Climate change funding in SA has largely focused on mitigation projects aligning with global efforts towards a global carbon-zero transformation. However, the region is in urgent need for adaptation actions that are properly funded and implemented. In the broader Latin America and the Caribbean (LAC) region, most climate funding comes from the Green Climate Fund, with additional funding from the Clean Technology Fund, the Amazon Fund, the Pilot Programme for Climate Resilience, the Global Environmental Facility, the Forest Investment Program, among others.[93] Only 18% of LAC climate funds are allocated to adaptation projects, with almost two-thirds of funding allocated to mitigation projects.

This indicator draws from the 2022 global *Lancet* Countdown report and monitors the allocation of

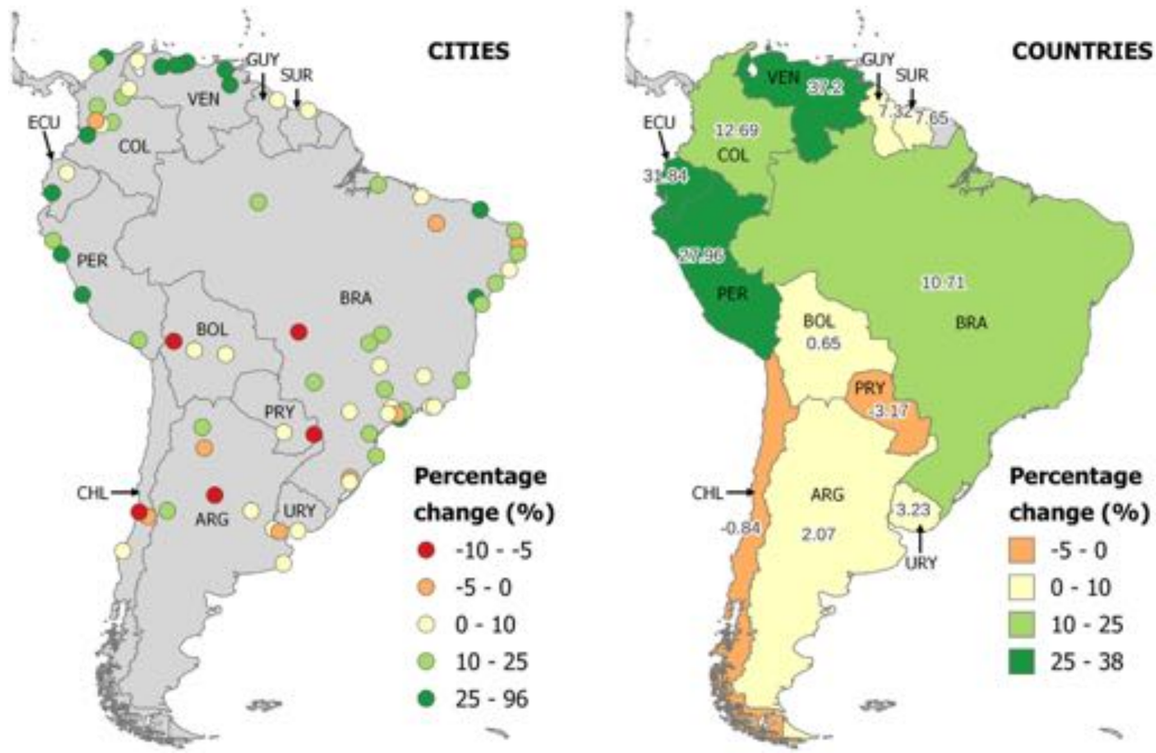

Fig. 4: Percent change in urban levels of greenness in cities (left) and countries (right) in SA, 2010–2021.

approved funds for health-related adaptation projects within the Green Climate Fund (GFC) by analysing and reviewing Project Approval Documents from the Project Portfolio.[94]

In 2021, approximately US$365 million were approved by the GCF for three projects related to climate change adaptation in SA. The approved projects in the database focused mostly on funding for adaptation technologies, bioeconomy products and services and coral reef protection. Only US$36.25 million, in two projects alone, were dedicated to health adaptation, specifically, representing just 10% of total approved funding. Furthermore, neither of these projects identified health benefits of adaptation actions or focused on health system resilience. The three projects were unequally distributed across the region, with all of them focused mostly on Brazil. No projects were approved in Argentina, Bolivia, Chile, Paraguay, Uruguay, and Venezuela.

With health adaptation woefully underfunded in the region, South American populations remain at high risk from climate hazards. Meanwhile, high-income countries have thus far not delivered US$100 billion a year by 2020 committed in the 2009 Copenhagen Accord, to support climate action in "developing nations".[95] Long-term financial investments, backed by political mandates on climate and health, are needed to strengthen the resilience of health systems and avoid the worst health impacts of climate change,

Indicator 2.3: vulnerability to mosquito-borne diseases—headline finding: average national vulnerability to severe dengue outcomes decreased in SA by 11% between 1990 and 2019. Bolivia experienced a reduction of 30%, whereas Argentina and Uruguay, located in the temperate Southern Cone, experienced increases in vulnerability

Changes in precipitation patterns, increases in temperature, and growing urban populations have favoured the distribution and expansion of mosquito-borne diseases globally, including dengue fever, which is of particular importance for SA.[96] Dengue is rapidly spreading to higher latitudes and less populated areas in Brazil and Peru.[6,8,97] While Argentina, one of the most urbanised countries in the world[98] has experienced the emergence and re-emergence of dengue in temperate regions, such as Cordoba,[96,99] Santa Fe,[100] and Buenos Aires.[101] In addition, Uruguay registered its first confirmed case of autochthonous dengue transmission in 2016.[96]

Vulnerability to mosquito-borne diseases, including the dengue virus, is influenced by biophysical, social, and economic factors and local coping and adaptive capacities.[102] Reductions in healthcare access and quality, urbanization, high population density, and low socioeconomic status are societal factors that can potentially increase population vulnerability to severe outcomes from dengue fever.[102–104] In a region with a high climatic suitability variance for the transmission of *Aedes*-borne diseases (indicator 1.3), information on vulnerability to dengue, combined with changes in the environmental suitability for its transmission, can assist countries of the region in investing in resilience and adaptation actions.

This indicator tracks the average national vulnerability to serious dengue-related adverse outcomes between 1990 and 2019. It combines the proportion of the population in urban environments,[105] with mortality of key preventable deaths (deaths by communicable diseases and maternal, prenatal and nutrition conditions) as a proxy indicator of healthcare access and quality.[106]

From 1990 to 2019, endemic countries in SA (Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, Venezuela, and Suriname) experienced an overall 16% decrease in vulnerability to dengue, although this outcome varied by country. Bolivia had a 30% reduction in dengue vulnerability, driven by improvements in healthcare access and quality, which rose by 55% since 1990. On the other hand, countries from the Southern Cone, where dengue is epidemic or emerging, experienced increases in vulnerability. For instance, Uruguay saw an increase in vulnerability (7%), mainly driven by the growth of the population living in urban settings (7% growth since 1990).

Argentina is the country that has experienced the highest increase in vulnerability to dengue (11%), mostly due to its large urban population (9 out of 10 people in Argentina live in urban areas) coupled with declining healthcare access and quality (3.4% decrease in 2019 compared to the 1990 baseline). In Argentina, this could be further exacerbated by healthcare provision and access inequities through its three coexisting healthcare subsystems (private, public, and social security).[107,108] Ensuring equitable access to healthcare is essential to provide early diagnosis and timely treatment during a dengue epidemic, thereby reducing the individual risk of the most severe dengue outcomes.[109] As metrics become available, future improvements in this indicator could include data on socio-economic status and context-specific climate variabilities such as those triggered by El Niño and La Niña events.

Conclusion

In SA, climate change adaptation for health is insufficient, putting local populations at acute risk of the most severe health impacts of climate-related hazards. Few countries in the region have conducted vulnerability assessments or developed HNAPs to guide adaptation interventions, limiting the articulation of specific health policies and interventions, and the capacity to guide resource allocation. As a result, there is a profound lack of financing at national levels and limited implementation of adaptation actions, as evidenced by few countries using climate information to guide health sector decision-making. Accordingly, the IPCC Sixth Assessment reports that the feasibility of implementing climate-informed tools for the health sector in Central and SA is limited due to political and institutional factors and financing.[11] Implementation science can support health adaptation planning by identifying best practices and bottlenecks in implementing adaptation actions, and the benefits of allocating further research resources to this area could cascade through broad areas of society.[115]

Despite these challenges, some signs of progress exist, particularly at the city level. Vulnerability to dengue fever, a disease that mostly affects urban populations, has declined in most South American countries, such as Bolivia, due to rising access to healthcare. Many cities are engaged in climate change risk assessments, and the region saw a 10% increase in the number of cities with moderate levels of urban greenspaces between 2010 and 2021. These incipient actions suggest that climate adaptation may be slowly occurring in urban areas in SA, but further efforts should be allocated to promoting evidence-based national-level adaptation action.

Panel 2: Resilient health systems.

Ensuring equitable access to high-quality healthcare services is a fundamental human right.[110] However, this right is threatened by social inequalities and healthcare disparities between and within South American countries, affecting vulnerable people such as indigenous peoples, women, children, elderly, migrants, and impoverished groups.[111] The growing burden of climate-sensitive diseases and health outcomes is straining already overloaded and fragmented healthcare systems in the region.[111,112] As the world aims to create climate-resilient healthcare systems, inter-ministerial action on social determinants of health and health information systems is urgently needed.[113,114] A priority in SA is to ensure universal healthcare access; securing essential services in health facilities such as water and sanitation services, electricity supply and internet connectivity; ensuring an adequate number of health professionals per capita and securing access to local healthcare for all; building climate-related technical capacities in local healthcare providers and providing climate change education to local healthcare professionals; investing in strengthening healthcare infrastructure and adaptation to climate change.

Section 3: mitigation actions and health co-benefits

Mitigation, or the reduction of GHGs in the atmosphere, can be achieved both via reduction of GHG emissions and via increases in carbon sequestration. Although SA is a relatively minor contributor to cumulative GHG emissions, a just implementation of mitigation actions is urgently needed in the region, to achieve global climate goals and to ensure the SA is not left behind in the global zero-carbon transformation. Moreover, SA is also home to important natural resources, such as the Amazon rainforest, an essential component of global carbon sequestration and sink. In agreement with this, SA countries have committed to meeting the Paris Agreement 2030 climate goals.[5]

Effective mitigation requires coordinated action by multiple actors, including the private sector, national and local governments, international organisations, and community members–and should involve all areas of the economy. Accelerated mitigation would not only avert the worst future health impacts of climate change, but also because many mitigation strategies have the potential to provide major and immediate health co-benefits. Focusing on these potential health gains, this section summarises the findings of indicators relevant to climate change mitigation and its associated co-benefits in the SA region and aims at providing better understanding of the local needs and support for planning climate actions.

For this inaugural report of the *Lancet* Countdown in South America, five indicators are presented: clean household energy, covering both access to clean fuels and technologies and exposure to household air pollution (HAP) (indicators 3.1.1 and 3.1.2); mortality from ambient air pollution by sector (indicator 3.2); sustainable and healthy road transport (indicator 3.3); and diet and health co-benefits (indicator 3.4). These will be further expanded in subsequent years.

Clean household energy

Indicator 3.1.1: access to clean fuels and technologies—headline finding: despite improved access to clean fuels and technologies for cooking, 23% of SA's rural population continue to use biomass fuels

Transitioning to clean fuels in the domestic sector is essential to meet the 7th Sustainable Development Goal (Ensure access to affordable, reliable, sustainable, and modern energy) and improve people's lives and livelihoods by reducing energy poverty. In turn, this is essential to meet countries' decarbonization commitments. According to the World Bank Global Electrification Database, more than 90% of the population in SA has access to electricity.[116] However, according to the International Energy Agency, a large percentage of this electricity is still produced from oil, gas and coal sources, showing the high dependency of the region on fossil fuels.[117] Biomass fuels are still used for cooking in many SA countries, resulting in high levels of air pollution in people's homes. Due to gender differences in cooking and time spent in the home in SA, the continued exposure to household air pollutants primarily affects women and children in the region, leading to various adverse health outcomes, from eye conditions to respiratory and cardiovascular illnesses and cancer.[118]

This indicator draws on data from 194 countries from national surveys provided by WHO. The surveys track the proportion of the population who use cleaner fuels and technologies for cooking, defined as those that have emission rate targets meeting WHO guidelines for air quality.[119,120]

In 2020, more than 90% of the SA population relied primarily on clean fuels and technologies for cooking, an increase of 15% since 2000 (Fig. 5). However, differences between countries in the region still exist. The data shows an upward trend in the last 20 years in all SA countries. Chile is the only country that has had universal access to clean cooking fuels and technologies since 1990, while Paraguay still lags, with just 69% of the population having access in 2020. The countries with the highest growth in clean household fuels for cooking are Guyana and Peru, with an increase from 35.6% and 43% in 2000, to 80.6% and 85% in 2020, respectively.

Nevertheless, these data do not account for regional differences between rural (23%) and urban (4%) settings. In the past two decades, urban populations in SA have had systematically greater access to clean fuels and technologies for cooking than those in rural regions. Despite the progress seen in countries such as Brazil, Colombia, and Guyana, disparities between rural and urban communities still exist. In 2020, the countries with the lowest use of clean fuels in rural areas were Paraguay, Peru, and Bolivia, with 40%, 42%, and 58%, respectively. All other SA countries' rural populations show percentages higher than 60% in clean fuels and technologies used for cooking.

This indicator will continue to evolve to better highlight rural communities' reality regarding clean fuel and technology use. It is important to note that the observed increase in clean cooking fuels and technologies in the past 20 years is mostly linked to liquified petroleum gas (LPG) subsidies. While LPG contributes substantially less to air pollution than solid fuels, it still contributes to GHG emissions. Moreover, as the current global energy crisis has exposed, LPG is subject to the price and supply fluctuation of the global fossil fuel industry, keeping families vulnerable to the health harms of energy poverty. On the contrary, new renewable technologies today offer a healthier source of energy in the domestic sector, which can be made available at the local level, independently of access to national grids or to volatile international fossil fuel markets. To have a real and just energy transition, the region needs to move away from fossil fuel use and start introducing renewable options.

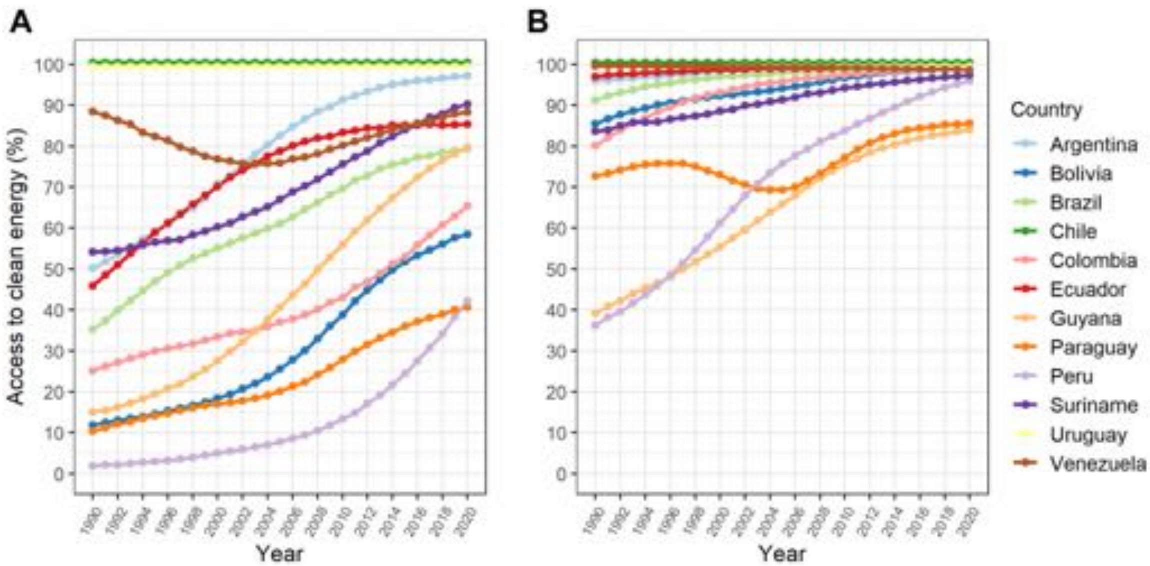

Fig. 5: Percentage of the **(A)** rural and **(B)** urban population with primary reliance on clean fuels for cooking, by country. Chile (green line) and Uruguay (yellow) have the same values.

Indicator 3.1.2: exposure to household air pollution (hap)—headline finding: exposure to HAP has a significant impact on public health in the South American countries. Transitioning from polluting fuels to clean fuels can reduce HAP for $PM_{2.5}$ personal exposure by 64%

Around 2.4 billion people worldwide[118] (nearly a third of the global population) use polluting fuels and low-quality (traditional) stove technologies for house heating and cooking. These fuels generate high levels of HAP as well as GHG emissions. There is, in addition, a significant inequality in access to cleaner fuels and technology between urban and rural areas. The same is observed for South American countries where 23% of its rural population continue to use biomass fuels exclusively (indicator 3.1.1).

For the purpose of analysing the HAP, a Bayesian hierarchical model was developed using sample data from an updated WHO Global Household Air Pollution database[119] to estimate an annual average 24-h HAP-$PM_{2.5}$ personal exposure for users of different fuel types (biomass, charcoal, coal, gas, and electricity) and stove technologies (traditional, improved) in rural and urban settings.[121]

Exposure to HAP from polluting solid fuels (biomass, charcoal, and coal) has a major impact on public health. There is, however, a large difference between the exposure level of polluting solid fuels and clean fuels (electricity and gas) in urban and rural settings in SA. In 2020, the estimated national-level 24-h weighted average HAP-$PM_{2.5}$ personal exposure in six SA countries (Argentina, Bolivia, Colombia, Ecuador, Peru, and Venezuela) showed that the use of polluting solid fuels for cooking and heating exposed populations to average values of 154 $\mu g/m^3$ [95% CI 111–191] of $PM_{2.5}$. More specifically, rural households have an annual average of 171 $\mu g/m^3$ [95% CI 155–187] of HAP-$PM_{2.5}$ and urban households 120 $\mu g/m^3$ [95% CI 48–191] (Fig. 6).

Switching to clean fuels can greatly reduce exposure to HAP and diminish the urban-rural health inequalities. The use of clean fuels, however, yields a national-level weighted annual average exposure of 53 $\mu g/m^3$ [95% CI 29–78], with rural households having an annual average of 65 $\mu g/m^3$ [95% CI 35–94] and urban households an annual average of 45 $\mu g/m^3$ [95% CI 21–69]. Transitioning from polluting fuels to clean fuels for heating and cooking can thus reduce the HAP-$PM_{2.5}$ personal exposure by 64% (62% in rural settings and 65% in urban settings). The annual average estimated HAP-$PM_{2.5}$ personal exposure for all fuel types exceeds the annual 5 $\mu g/m^3$ threshold recommended by the WHO.[122] The results thus indicate that policy interventions are needed to rapidly increase the proportion of the population with access to clean fuels and improved stove technologies by 2030 so as to address health inequities and mitigate climate change globally and, in particular, in SA.

Indicator 3.2: premature mortality from ambient air pollution by sector—headline finding: in 2020, about 37,000 premature deaths in SA were associated with ambient $PM_{2.5}$ pollution. Chile and Peru have the highest mortality per million of all the countries in the region

Air pollution is an environmental health risk factor, associated with seven million premature deaths every year worldwide.[123] In addition to this, $PM_{2.5}$ exposure leads to a high burden of disease through associated

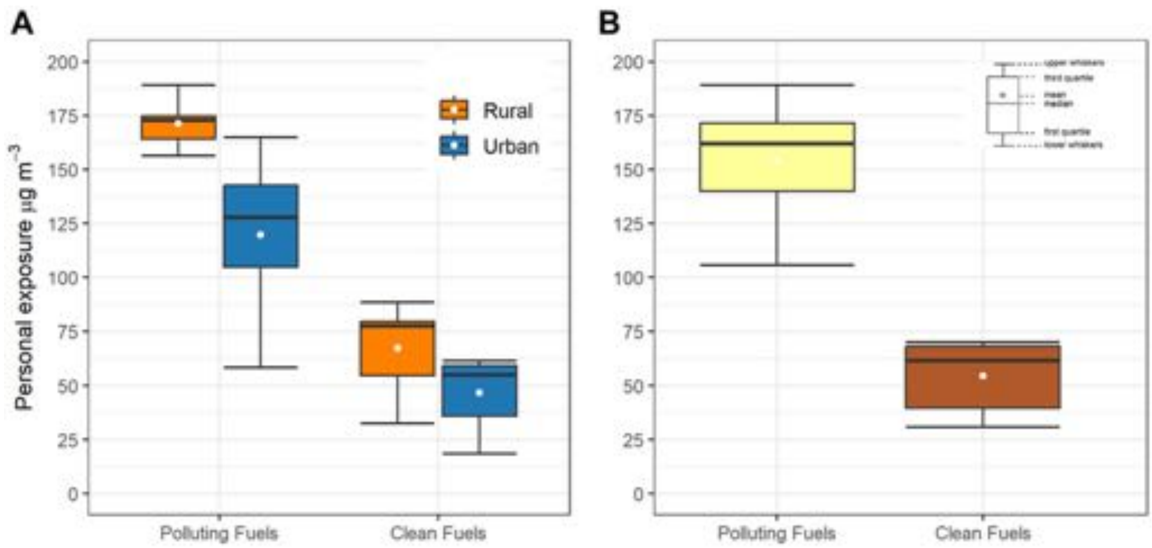

Fig. 6: Estimated weighted average of 24-h HAP-PM2.5 personal exposure due to polluting solid fuels and clean fuels for **(A)** urban and rural, and **(B)** national level. Also shown are the median, upper, and lower quartiles.

morbidity, as it increases the risk of stroke, heart, lung, lower respiratory diseases (such as pneumonia), cancer, among others. The SA region is one of the most urbanised areas of the world, with 80% of the population living in urban areas. Yet, most SA countries have set air-quality standards at WHO interim targets; thus, none are currently putting efforts towards ensuring the air their populations breathe meets the WHO's $PM_{2.5}$ maximum threshold of 5 $\mu g/m^3$.[122]

Urban residents are generally the most exposed to air pollution, due to the emissions of mobile and stationary air pollution sources (i.e., electricity generation, transportation, waste burning, and agriculture). In addition, air quality can be worsened by increased temperatures, highlighting the urgency of responding to these challenges as the planet heats. Importantly, since pollution and climate change share common emission sources, effective climate mitigation measures could lead to direct health co-benefits from short and long-term improvements in air quality, contributing to saving millions of lives, and substantially reducing the burden of disease, each year.

This indicator, adapted from the 2022 global *Lancet* Countdown report, presents an estimation of the source contributions to ambient $PM_{2.5}$ and their health impacts by country, and by individual economic sectors. Estimates of sectoral source contributions to annual mean exposure to ambient $PM_{2.5}$ were calculated using the Greenhouse gas–Air pollution Interactions and Synergies (GAINS) model[124] which combines bottom-up emission calculations with atmospheric chemistry and dispersion coefficients.

This indicator estimates that, in 2020, 37,100 premature deaths were attributable to ambient $PM_{2.5}$ in SA, a slight increase from the 36,600 deaths estimated to have occurred in 2015. Of the deaths estimated in 2020, 10,100 (27%) were attributed to transport, 6600 (18%) to industry and 5100 (14%) to the waste sectors. The SA countries with the highest mortality rate attributable to exposure to $PM_{2.5}$ are Chile and Peru, with 230 and 176 deaths per million. In SA, Peru and Bolivia have the worst air quality. Peruvians are exposed to an ambient air pollution average of 31 $\mu g/m^3$ a year and Bolivians to 27 $\mu g/m^3$, more than five times higher than the WHO guidelines.[125]

Despite the health impacts of exposure to ambient air pollution in SA, and the substantial potential for immediate health benefits of accelerated climate change mitigation, implementation barriers, capacity gaps and limited air quality monitoring networks hinder progress towards clean air. This poses the challenge that the potential co-benefits of the climate mitigation interventions on air quality might not be maximised, nor adequately accounted for in the cost-benefit analysis of local climate action. Expanding air quality monitoring networks will become increasingly relevant to track and ensure the maximisation of the health gains of climate action, especially as countries in the region work to implement the ambitions laid out in their HNAPs and NDCs.

Indicator 3.3: sustainable and healthy road transport—headline finding: between 1971 and 2019, SA has increased the per capita use of energy for road transport by 138%, and in 2019 fossil fuels were 84% of their energy used for this purpose

Transportation is an essential part of the economy and daily activities. Motorised road transport allows access to goods, services, and jobs to support social and economic wellbeing. At the same time, motorised road transport is also responsible for multiple health risks, such as air pollution, traffic injuries, and physical inactivity. Climate mitigation strategies have focused on increasing access to public transportation, active forms of travel, and electrifying road transport to reduce direct emissions of GHG from engine exhaust. These transitions also have the potential to improve air quality, increase physical activity, and provide just access to public transport systems, directly impacting public health. As mentioned in indicator 3.2, it was estimated that in 2019 SA lost more than 10,000 premature deaths due to air pollution from transport sources.

This indicator describes the trend in per capita energy use for road transport in SA and delineates the changes in fuel type used by the country. It was derived by combining the fuel use data (by fuel type) reported by the IEA, World Extended Energy Balances,[117] with the country population reported by the United Nations population estimates in 2019.[24]

Since 1971, SA has increased the per capita use of energy for road transport by 138%. Specifically, countries like Bolivia, Ecuador, Guyana, and Paraguay, have tripled their per capita energy use in road transport since the 1970s. This has happened in parallel with a rapid urbanisation process and increased car sales in the region.[126,127] Fossil fuels in 2019 were the main energy source for road transport in SA, accounting for 84% of the road transport energy, followed by biofuels (16%). Electricity accounted for only 0.04% of all the energy used for road travel in the region.[5] Since 1971, fossil fuel use from road traffic has decreased by 5% in SA, primarily at the expense of biofuels that have grown by 200%.

Countries like Argentina, Brazil, Colombia, Paraguay, Peru, and Uruguay have been the region's main users of biofuel for road travel. However, biofuels still emit GHGs, and contribute to health-harming air pollution. In contrast, other countries like Chile and Ecuador are leading the road travel electrification in the region. Yet, in both countries electricity accounts for less than 1% of the road energy usage.

In SA, climate mitigation strategies that focus on reducing road traffic energy consumption, dependency on motorised transport, electrifying road transport, transitioning to clean energies, and shifting to public and active modes of transport are needed to achieve the Paris climate commitments in the region. Implementing these climate mitigation policies will also offer great opportunities to improve public health priorities such as air and noise pollution, traffic safety, physical activity, and equitable access to transport services.[128]

Indicator 3.4: diet and health co-benefits—headline finding: in SA, 638,000 premature deaths were attributable to imbalanced diets in 2019, 23% of those have been linked to a high intake of red and processed meat and dairy products

Food consumption is one of the most important determinants of health. Diets rich in whole grain cereal, legumes, vegetables, and fruits can reduce non-communicable diseases and expand life expectancy. On the contrary, high meat, sugar, or fat consumption can increase disease incidence and premature mortality.[129] Food production also impacts the environment and the climate, and the global food system is responsible for about one-third of all global GHG emissions.[130] Cattle and cattle feed production are major contributors to agricultural emissions, mostly driven by land use changes and ruminant fermentative processes.[27] In addition, the associated soil degradation and deforestation can contribute to increased droughts, land erosion and loss of carbon sinks.

SA is one of the most important producers of livestock and soybeans globally.[131] However, when it comes to public health, the scenario needs attention and changes, especially those related to the incidence of non-communicable diseases associated with the excessive consumption of red meat, processed meat, and dairy products. It is worth noting that cultural and eating habits in the region favour unhealthy patterns of food consumption and a high associated burden of disease in the region.[132] Strategies for change have been proposed at all levels, from civil society to government agencies, through the public and private sector.[133]

This indicator draws from the 2022 global *Lancet* Countdown report and assesses deaths attributable to dietary risk factors using data on food consumption and mortality rates by country. The baseline food consumption was assessed based on the estimates from the Food and Agriculture Organization (FAO) food balance sheets and adjusted for the amount of food wasted at the point of consumption.[134] Attributable premature mortality from high consumption of red meat was estimated by a comparative risk assessment approach, using dose–response functions for food consumption and health outcomes reported in the scientific literature.[1]

Across SA in 2019, approximately 150,100 deaths were attributable to high consumption of red meat, processed meat and dairy products. Argentina and Brazil have the highest number of premature deaths attributed to high red meat, processed meat and dairy products consumption with 26,600 and 91,300 respectively. Overall, since 2010, there has been a 28% increase in premature deaths attributed to high consumption of red meat, processed meat, and dairy products in SA. In parallel, GHG emissions related to red meat and dairy production in the region have increased 28% since 2000.

Understanding that food is the single strongest lever to optimise human health and environmental sustainability on earth,[135] this indicator highlights the need for a dietary transition aimed at reducing food sector emissions, while simultaneously and delivering the health co-benefits of increasing in plant-based food consumption, and reducing the consumption of animal-source food.[135] A more conscious evaluation of food groups, their nutritional characteristics, and their best use could guide policymakers, companies, and consumers about their shared responsibility in promoting healthier diets, considering the multiple implications of food choices for health and the environment.[136]

Conclusion

Accelerating action toward a low-carbon transition could yield major benefits to SA in the long and immediate term. The health gains from climate mitigation are a major component of this and include improved health from net zero-carbon and healthier diets; sustainable agricultural, and land management practices; better, people-centred, and healthier urban planning and reduced dependency on motorised transport; improvements in air quality; and less reliance on volatile international fossil fuels markets and reduced energy poverty. SA also has important natural resources that, if preserved and supported, could help sink and sequester GHG faster than only relying on reducing carbon emissions. Preserving SA natural resources will also support healthier communities, improve food security, and provide cleaner environments for indigenous, local, and regional communities. If the economic development proposed by governments and private sectors in the SA region prioritises climate actions, it will support healthy communities, less stress on local health systems, a better environment, and job creation, in parallel to supporting the regional commitments to the Paris Agreement goals.

Section 4: economics and finance

Section 1 described the health impacts of climate change in SA, while sections 2 and 3 outlined efforts to minimise impacts through health-centred climate adaptation and mitigation. Designing cost-effective policies to protect human health from changing climatic conditions requires understanding the costs these health effects entail, and any sustained investment needed to reduce or avoid them (Panel 4). Investments that positively impact health require considering the costs and opportunities of transitioning to zero-carbon economies. Infrastructure and social spending needed to meet climate goals in LAC has been estimated to range between "*7% and 19% of gross domestic product (GDP) by 2030 (US$470 billion to US$1300 billion in 2030) depending on initial conditions and proposed economic and social targets*".[140]

However, benefits are expected to be greater than this spending; reducing dependence on fossil fuels and their subsidies is consistent with promoting health and wellbeing. However, transitioning to a zero-carbon economy requires political will and careful consideration of how to implement it without undermining the socio-economic determinants of health and deepening inequalities in an already highly unequal region.

This section tracks the economic costs of the health impacts of climate change and the economics of transitioning to zero-carbon economies in SA. The first three indicators estimate the economic costs that climate change's health impacts might already be

Panel 3: Tree cover loss and climate change.

The South American region is known for its important natural areas like the Amazon rainforest or the Patagonian ecosystems. Trees and vegetation are key components of the carbon cycle and can help reduce the accumulation of CO_2 in the atmosphere by transforming it into biomass through photosynthesis. Acting this way as "carbon sinks," they are an essential resource in climate change mitigation. Brazil is one of five countries that collectively contain 49% of the world's total biomass.[137] From 2001 to 2021, Brazil lost 62.8 Mha of tree cover, equivalent to a 12% decrease in tree cover and 34.5 Gt of CO_2e emissions.[137,138] This deforestation was mostly driven by land clearing for the intensive production of commodity goods (e.g., soy, beef, logging).[137,138] Findings are similar in other countries. For example, the tree cover in Paraguay has decreased by almost 27% (equivalent to 1.61 Gt of CO_2e emissions) since 2000.[137]

Deforestation is a driver of health risks. It can lead to an increased risk of spread of infectious diseases; exacerbate food insecurity of nearby communities, with indigenous communities particularly at risk; reduce local availability of clean drinking water; increase soil degradation and erosion, in turn exacerbating dust pollution, or the increased risk of floods; and other hazards. Furthermore, the intense production of commodity goods associated with deforestation also leads to increases in health risks, including those stemming from the use of agrochemicals or the displacement of indigenous and local communities. Policies and behavioural changes that support more healthy diets relying less on red meat or crops monoculture, could help reduce deforestation in the region while simultaneously minimising the associated health harms.[139]

Strategic improvements in land management and economic development focusing on sustainable agricultural patterns can deliver better use of local land and water resources. Other causes of tree loss, such as wildfires, have been related to climate events like droughts and extreme heat. SA will benefit from climate mitigation actions that help minimise the risk of such climate events.[138]

Finally, urbanisation and sprawl are other drivers of forest loss in the region, and policies that prevent sprawl and support sustainable urban planning can benefit climate mitigation and health co-benefits.[128,138]

imposing on society. The fourth indicator analyses the net value of fossil fuel subsidies and carbon prices in SA countries.

The economic impact of climate change and its mitigation

Indicator 4.1.1: costs of heat-related mortality—headline finding: the monetised value of heat-related mortality of people aged 65 and older in SA was estimated as the equivalent of the average income of 485,000 local workers in 2021

Heat-related mortality is a major threat to South American communities. This indicator uses data from the 2022 global *Lancet* Countdown report to estimate the monetised value of heat-related deaths of senior inhabitants (i.e., aged 65 and older), as defined in indicator 1.1.2. This estimate provides a comparative monetised value of the health impacts of heat exposure and can justify the need for a cost-benefit analysis for climate action. For comparison purposes, the indicator expresses the cost of deaths in terms of an average local person's annual-income equivalent.

The total monetised value of heat-related deaths in South American countries has steadily increased since 2000, peaking in 2020 with a monetised loss equivalent to the income of 700,000 people on average (Fig. 7). The annual average monetised losses in the period 2016–2021 in SA were 150% higher than the baseline average for the period 2000–2005. This represents over twice the global average, with global monetised losses associated with heat-related mortality increasing by 73% over the same period. Specifically, Brazil reports the highest total monetised losses from heat-related mortality in 2021, followed by Argentina and Colombia. For most countries in the region, heat-mortality costs have more than quadrupled over the past 20 years, with Colombia and Ecuador leading the path.

These monetised values should be interpreted as a lower bound, as they only consider heat-related mortality from senior citizens. Given the socio-economic and environmental characteristics of the region, it can be expected that other age groups (especially children under 5) will be affected by increasing temperatures and heatwaves through different pathways. Higher temperatures translate into more deaths due to vector-borne diseases such as dengue, and other causes such as accidents, homicides, and conflict.[141,142] These events primarily affect children and young adults.

Indicator 4.1.2: loss of earning from heat-related labour capacity reduction—headline finding: in SA, the construction and agricultural sectors are the most affected by the potential loss of earnings from heat-related labour capacity reduction. Each sector represented 34% of the US$22 billion in total potential income losses from labour capacity reduction due to extreme heat for the region in 2021

Heat not only affects workers' health but also their labour productivity, generating potential income losses that could affect the wellbeing of themselves and their families. It also affects the overall productivity of a country and its development capacities. This indicator, drawn from the 2022 global *Lancet* Countdown report, uses country-level heat-related labour capacity loss (expressed as potential work hours lost) across four sectors (services, manufacturing, construction, and agriculture), and estimates the potential loss of earnings by multiplying this labour capacity loss with the average earnings per hour for each country, sector, and year.

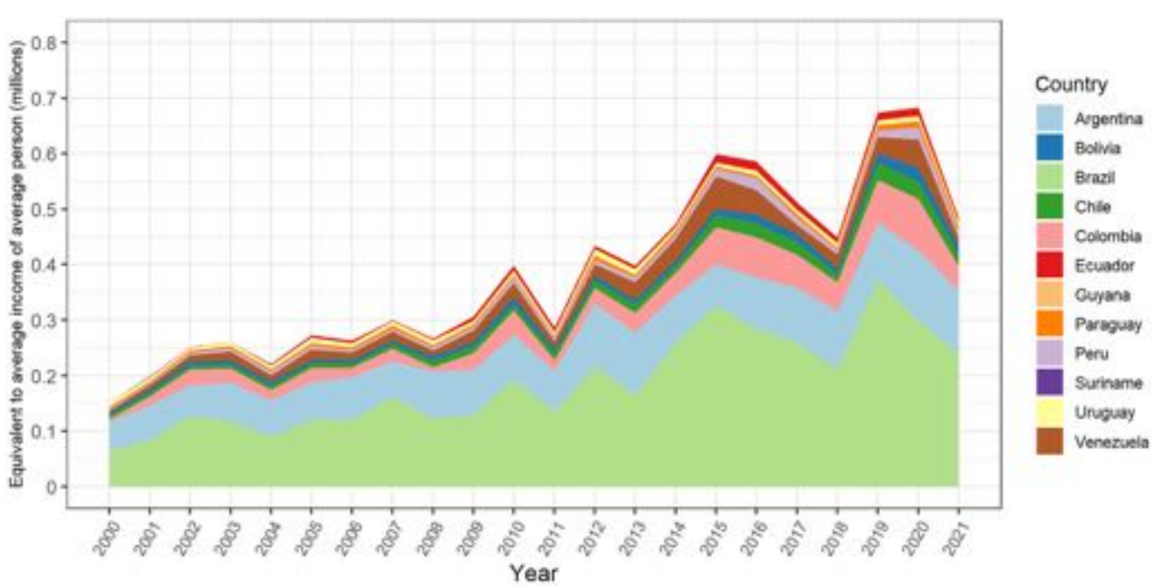

Fig. 7: The monetised value of heat-related mortality in SA from 2000 to 2021 (in average income equivalent).

In 2021, average potential income loss from heat-related labour capacity reduction represented 1.60% of national GDPs in SA, with Venezuela having the highest total potential loss as a proportion of GDP (10.6%) and Chile the lowest (0.02%) (Fig. 8). Total potential income losses that year amounted to US$22 billion (0.68% of the regional GDP). The highest potential income losses are estimated to occur in the construction and agriculture sectors, where the work demands more physical power, and where workers are the most exposed to the elements and have limited capacity to shelter. In 2021, the countries with the highest total losses were Brazil and Venezuela with US$11.2 and US$4.8 billion, respectively.

In most countries of the region, the losses as share of GDP have declined over time, reflecting mainly the growth of GDP and probably a decrease in the contribution of outdoor activities. When comparing the results of 2020, it is relevant to recall that many countries had a sharp fall in their GDP due to the COVID-19 pandemic. In some countries, potential income losses increased for that year and then decreased in 2021 (Bolivia, Colombia, Chile, Ecuador).

Indicator 4.1.3: costs of the health impacts of air pollution—headline finding: the monetised value of premature mortality due to air pollution in SA was equivalent to the average income of 2.9 million people in 2020

Air pollution is closely related to GHG emissions; thus, its mitigation will also reduce the costs of the health impacts of mobile emission sources such as transportation, and stationary sources like power plants, refineries, and industries.[143] This indicator draws from the 2022 global *Lancet* Countdown report and tracks the mortality cost due to ambient $PM_{2.5}$ air pollution by providing a monetised valuation of the years of life lost (YYLs) that result from exposure, as per indicator 3.2.

In 2020, the monetised costs of premature mortality due to air pollution in SA were equivalent to the average income of 2.9 million people. Chile and Peru registered the highest losses, equivalent to 1.57% and 0.83% of their GDP, respectively (or the equivalent average income of 300,000 and 275,000 people, respectively).

Beyond these direct impacts, air pollution leads to additional economic losses indirectly, including through increased morbidity, reduction in labour capacity, or economic disruption from exposure control measures. Quantifying these losses is essential for an adequate cost-benefit analysis of climate action.

Indicator 4.2 net value of fossil fuel subsidies and carbon prices—headline finding: the seven countries reviewed in SA had a net-negative carbon price in 2019, reflecting an overall subsidy on fossil fuels that represented a large proportion of the national health budget

Carbon pricing and fossil fuel subsidies can provide financial incentives that promote or hamper transitions towards renewable energy sources. Not all countries in SA set a carbon price or provide information to explore these dynamics; however, the available data in SA suggests that, even in the cases in which countries implemented carbon pricing instrument is available, these are undermined by substantial subsidies to fossil fuels.

This indicator draws from the 2022 global *Lancet* Countdown report and combines data on carbon taxes and fossil fuel subsidies, to estimate a net carbon price at a country level. It uses information from IEA and

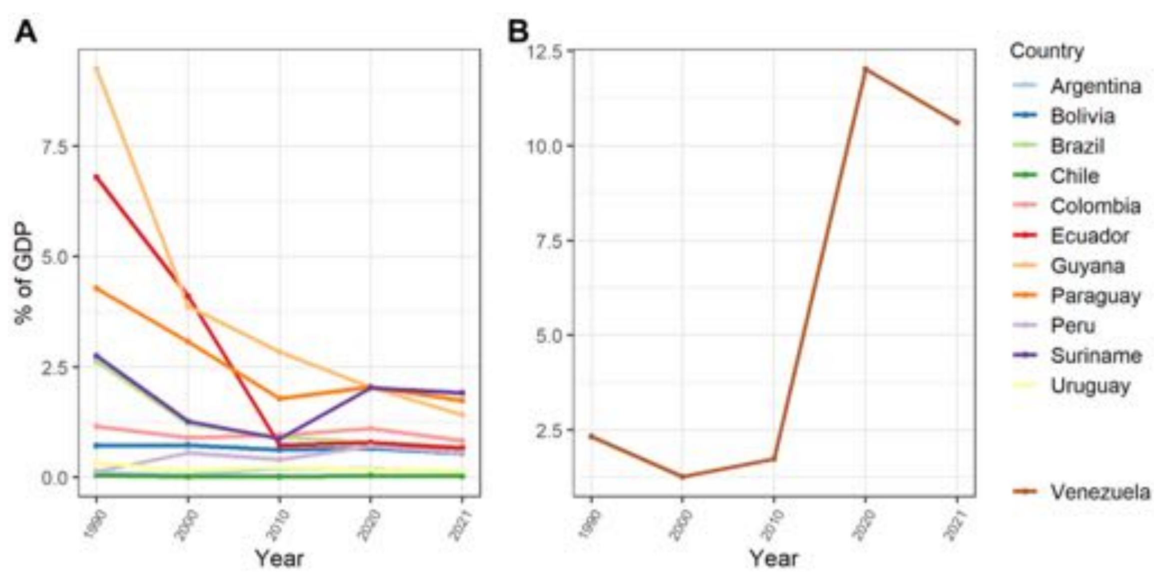

Fig. 8: Potential income loss from heat-related labour capacity reduction in **(A)** SA countries, except Venezuela and **(B)** Venezuela as a percentage of their GDP.

OECD on fossil fuel consumption subsidies and the World Bank Carbon Pricing Dashboard on carbon prices to estimate net-economy-wide average carbon prices and revenues. For carbon taxes, data is available for only seven out of the 12 countries in SA, namely Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, and Venezuela.

Information from 2019 reveals that, considering all subsidies and all carbon taxes, all these countries have net negative carbon prices, indicating a net subsidy of fossil fuels. Venezuela, Argentina, and Bolivia providing the largest net subsidies per unit of carbon (−96.2, −42.2, and −33.4 real 2021 US$/tonne, respectively). Though subsidies have fallen for all countries except for Venezuela since 2010, the average net-carbon price remained at −41.6 real 2021 US$/tonne for the region in 2019 (Fig. 9). These net subsidies were equivalent to an average of 10.5% of health spending in the region in 2019. For Venezuela, Ecuador, Bolivia, and Argentina these net subsidies are equivalent to 85.6%, 29.2%, 23.5%, and 15.4% of their health expenditure, respectively. These net subsidies equivalents range between 3.5% and 4.8% for Brazil, Chile, and Colombia.

Removing fossil fuel subsidies and implementing carbon taxes is essential to ensure their price reflects the true costs of fossil fuel burning to health, to the broader economy, and to promote a low-carbon, healthy transition. Countries in SA collectively spent US$27.9 real billion on net fossil fuel subsidies in 2019. Such spending could be redirected towards health-related actions, education, zero-carbon energy, or to a different use, with focus on supporting vulnerable households that might be overburdened by any potential increase in energy prices. Such approach has the potential of enhancing overall health and wellbeing.[144]

Ensuring robust support to those who might be overburdened by the elimination of fossil fuels is essential in SA, as both the general public as well as interest groups are very sensitive to changes in the price of fuels. Energy represents a large share of the expenditures of lower income families. For other fossil fuel users, like taxis, or trucks, and other energy intensive activities, an increase in prices can translate into significant income reductions. Increases in the price of energy can therefore undermine the socioeconomic determinants of health and translate into substantial social costs that trigger political demands difficult to ignore by governments. Thus, a successful reduction in fossil fuel use needs to be accompanied by a set of policies that would prevent negative immediate socioeconomic consequences. Any policy aimed at removing fossil fuel subsidies in SA should therefore consider implementing transfer programs to vulnerable populations that depend on fossil fuel subsidies, and improving access to affordable clean energy, public transport and zero-carbon transport technology that allows substitution away from fossil fuel-based energy.

Conclusion

The data available for South American countries suggests that the health costs of climate change have increased over the past 20 years. The monetised value of heat-related and ambient air pollution deaths in SA have risen at faster rates than the world averages. Transitioning to a zero-carbon economy, which is essential, to protect human health, requires political will. But the

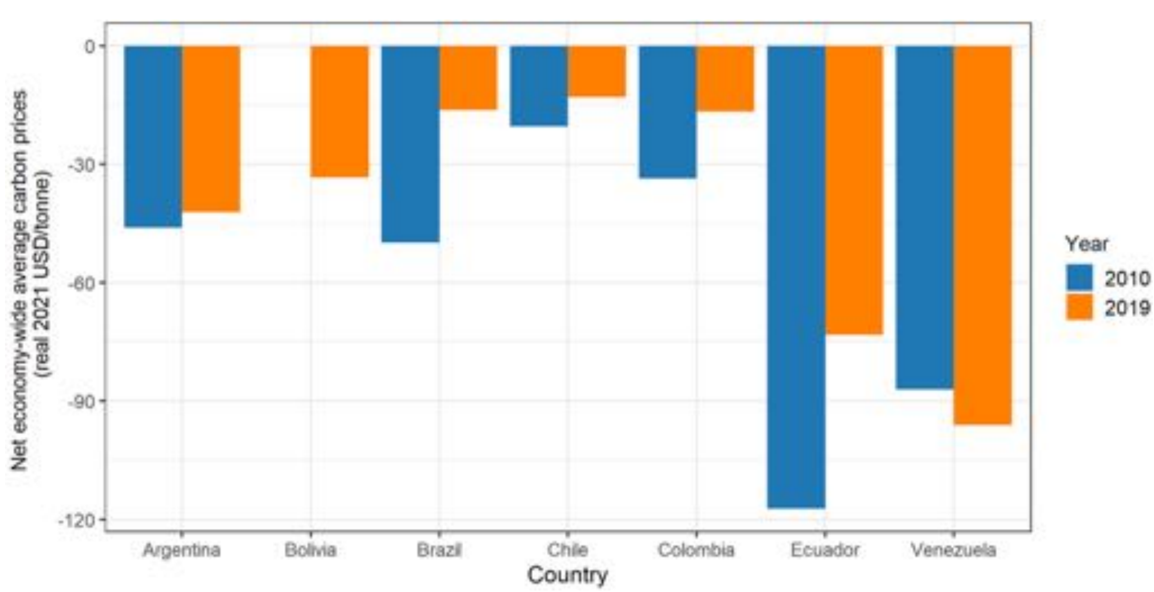

Fig. 9: Net economy-wide average carbon prices (real 2021 USD/tonne).

removal of fossil fuel subsidies should be accompanied by well-planned policies to prevent any potential increase in energy prices from affecting vulnerable populations. Such policies could include, redirecting spending, implementing green tax reforms, generating new income sources to replace revenues from fossil fuel sales, and increasing the availability and access to affordable and zero-carbon energy sources. Although many South American countries such as Brazil, Colombia, Chile, and Ecuador rely on hydroelectric power for generation and are including solar and wind in their energy mixes as alternatives, further efforts should be promoted so that the region as whole transitions towards a net zero-carbon economy. For SA, there is also a need to implement policies to reduce air pollution from transportation, forest fires, deforestation emissions, and land use changes, all of which would not only render health benefits, but also reduce economic losses. It should be noted that this section did not use all the global indicators, because of the lack of data limiting the indicators to the ones available. Further work is needed on identifying and collecting data for the region, that can produce more precise and detailed analyses.

Panel 4: Understanding the costs linked to dengue fever transmission.

Dengue fever is endemic in most of SA, with 16 million cases registered in 2011–2021.[145] Dengue epidemics are frequent across many South American countries, and the emergence of dengue in countries from the Southern Cone has also been recorded in recent years.[96,99,101] Indicator 1.3 shows that the climate suitability for the transmission of dengue in SA has increased by 35.3% over the past decade and that highly urbanised countries from the Southern Cone (Argentina and Uruguay) have experienced increases in the vulnerability to severe dengue outcomes (indicator 2.3). Dengue outbreaks and epidemics disproportionately affect children, increase mortality and morbidity, and overburden local health systems. The economic costs and societal burden this disease entails is substantial and often underestimated in countries of the region, like Brazil and Argentina.[146–148]

Understanding and quantifying the economic costs of dengue in terms of the value of dengue-related mortality and the cost of treatment, is essential to the development of accurate cost-benefit analysis that can guide preventive public health policies and interventions that reduce the propagation of the disease and its socioeconomic burden. It can also support South American countries in the design and implementation of adaptation measures to this public health threat which is exacerbated by a changing climate. Countries would therefore benefit from tracking premature mortality and treatment costs associated with dengue in the region and incorporating this evidence in their policies to reduce the burden of this climate-sensitive disease.

Section 5: public and political engagement

Climate change is the biggest global health threat of the 21st century, and climate action could be the biggest global health opportunity we face.[9,149] Mitigation and adaptation actions aligned with the commitments under the Paris Agreement essential to protect people's health and wellbeing in the context of a changing climate and ensure no one is left behind in the zero-carbon transition. Such actions must be underpinned by awareness and commitment from policy makers, private organisations, and the general public, all of which are informed and influenced by the media and scientific publications. Despite the inextricable links between health and climate change, and the high stakes involved, awareness of these links among South American populations is still relatively low. Reduced media coverage, and a limited number of scientific publications in Spanish, making misinformation at different levels of the population one of the most urgent problems in the Global South. Measuring public and political engagement across time can help identify current barriers and limitations in the understanding of the links between health and climate change in SA (Panel 5), as well as monitor changes in such understanding as the global conversation evolves. This in turn can help tailor engagement campaigns towards ensuring relevant stakeholders can be informed to enable the zero-carbon transition.

This section tracks engagement in health and climate change by news media, scientists, governments, and the corporate sector. Indicator 5.1 tracks news coverage of health and climate change across eight newspapers in SA. Scientific publications are one of the main sources of the evidence used by governments, corporations, and civil society to inform priorities and action on climate change (indicator 5.2). Governmental engagement (indicator 5.3) is tracked with mentions on the health and climate change intersection in the 2021 UN General Debate (UNGD) and South American governments' mentions of health-related terms in NDC. Finally, engagement of the corporate sector (indicator 5.4) is tracked by examining the mentions of health-related terms in United Nations' Global Compact Communication of Progress (GCCOP) reports.

Indicator 5.1: media coverage of health and climate change—headline finding: in 2021, coverage of health and climate in key newspapers from eight countries in SA reached its highest level since 2007 and continued a three-year upward trend. However, it did not match the relative increase in overall coverage of climate change from 2020

News coverage can place key issues on the public and political agendas. Thorough and frequent coverage of health and climate change would suggest it is an issue that needs to be addressed by governments and society. It can also help promote a better understanding around the urgency and potential benefits of accelerating health and climate action. This indicator draws from the 2022 global *Lancet* Countdown report, and tracks news coverage of health and climate change in newspapers from eight countries in SA (no data were available for Guyana, Paraguay, Suriname, and Venezuela). The searches were conducted using a set of keywords in Spanish (for Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, and Uruguay) and Portuguese (for Brazil) in three news article databases (Nexis Uni, Proquest, and Factiva).

The results for co-coverage of health and climate were compared to searches for general coverage of climate change in the selected newspapers, although the number of newspapers included in the analysis is limited. The data might therefore not accurately represent how SA media more generally covers health and climate change, nevertheless, this indicator helps to monitor trends in leading newspapers in each of the eight countries included in the analysis (*La Nación* in Argentina, *La Razón* in Bolivia, *O Globo* in Brazil, *El Mercurio* in Chile, *El Tiempo* in Colombia, *El Comercio* in Ecuador, *El Comercio* in Perú, and *El País* in Uruguay).

Co-coverage of health and climate change reached a record of 672 articles during 2021 in the leading newspapers of the eight South American countries analysed, which represents an increase of 156% from 2007 to 32% when compared to the previous year. Also, a three-year upward trend has been observed in articles mentioning both health and climate change-related keywords (377 in 2019; 508 in 2020; 672 in 2021). At the same time, an upward trend has been observed throughout 2021, with an increase of 121% from the first quarter to the fourth quarter (107 first quarter vs 236 fourth quarter) across all sources.

However, the increase of 32% in co-coverage of health and climate change for 2020–2021 did not match the relative increase in general coverage of climate change (86%), which reached its highest level since 2007 in all sources combined (2384 articles). Moreover, the relative attention that health is getting in the broader media coverage of climate change is decreasing. In 2021, the number of articles of health and climate change represented 28% of total climate change coverage in all sources combined, while it represented 40% during the year before.

These trends in news coverage in SA could be a function of obstacles related to journalists' working routines, limited access to data or sources, lack of specialisation, among others. An analysis of a more diverse group of sources per country (more than one newspaper, or also TV sources, which have more reach), and the inclusion of newspapers and other media from countries that are not currently being monitored, could also help to identify trends that could be more representative.

Considering the analysed newspapers, *El Mercurio* from Chile published the highest number of articles on health and climate change in 2021 (184), although it represents a 1% decrease from the previous year (186 articles) and it did not match the paper's increase in general coverage of climate change (29%) (Fig. 10). The two newspapers which showed the most significant increase in health and climate change coverage in the 2020–2021 period were *O Globo* from Brazil (557%) and *La Nación* in Argentina (293%), which also showed an increase in general coverage of climate change (733% and 461% respectively). At the same time,

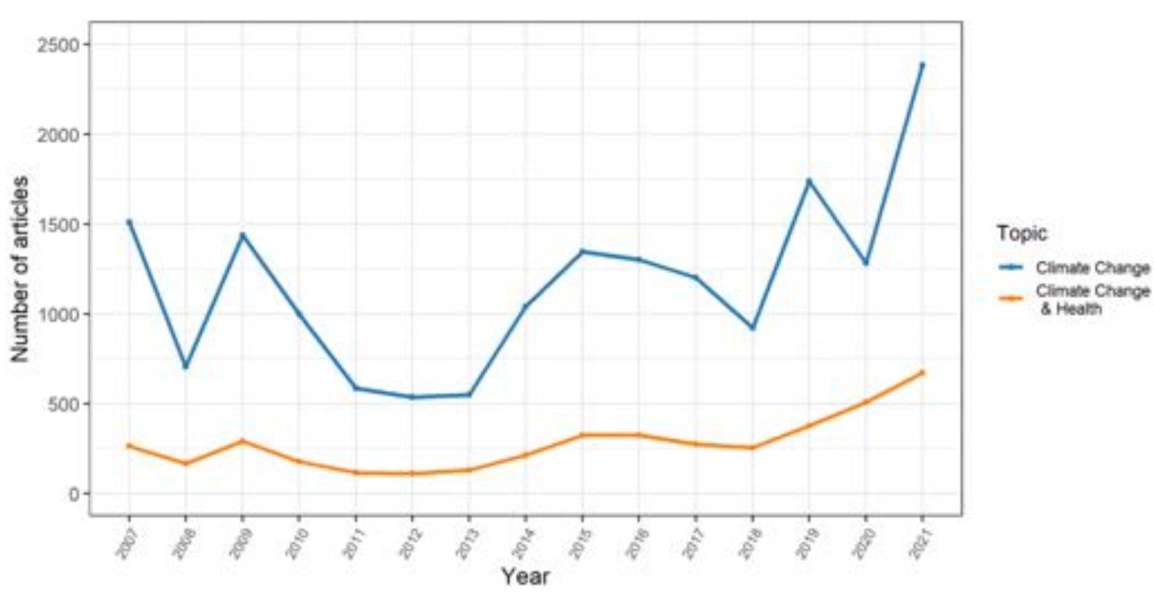

Fig. 10: Newspaper engagement measured by total coverage of climate change, and health and climate change co-coverage, in eight key newspapers from eight countries in SA (2007–2021).

although the general coverage of climate change remained similar in *El Tiempo* from Colombia between 2020 and 2021 (with a 4% decrease), it showed a higher decrease (28%) in co-coverage of health and climate change for the same period (153 articles in 2020, 110 in 2021). This indicator will continue to evolve, with future iterations of the report aiming to add more relevant media outlets and main topics covered for each South American country.

Indicator 5.2: scientific engagement in health and climate change—headline finding: original research on health and climate change focusing on South American countries increased by 1107% between 2007 and 2021, driven primarily by interest in Brazil. In 2021, 93.9% of the health and climate change articles referred specifically to impacts on health, while 6.1% focused on mitigation and 5% addressed adaptation actions with some scientific papers covering both topics

Scientific evidence is an essential asset for media outlets, individuals, and governments that shapes public, private, and political engagement with health and climate change and, importantly, which can inform local and global change.[150,151] A broad scientific, political, and civic input and effort is required to maximise the diversity of knowledge and support multiple pathways of transformation toward a healthy, sustainable compatible future.[152] Strong informational, technological, and scientific capacity to produce scientifically sound evidence is needed to guide appropriate policies and interventions and protect people's health from climate change-induced risks.

This indicator measures scientific engagement on health and climate focusing in the 12 countries in SA by tracking the number of scientific publications. A machine-learning approach was used to explore developments across major research domains (mitigation, adaptation, impacts), the health impacts covered, locations studied, and the authorship patterns. Only English-language peer-reviewed articles were collected from the scientific databases Web of Science, Scopus, or MEDLINE.

In 2021, 181 articles in SA covered health and climate change, which has been the highest recorded number since 2007 (Fig. 11). An upward trend in scientific engagement related to health and climate change in SA has been maintained, with the number of articles related to these topics increasing by 1107% between 2007 and 2021. Most of the health and climate articles focused on impacts (94%), rather than mitigation and adaptation. Brazilian institutions have driven the overall increase in publication since 2007. 57.5% of the publications mentioned or were carried out in Brazil. Moreover, 64.7% of the overall publications had authors affiliated with a Brazilian university.

Publications since 1990 were analysed and grouped into five topics: health impacts (45.7%), exposure (20%), intervention options (5.3%), mediating pathways (vulnerabilities and social determinants of health) (7.3%), and other method topics (21%). Regarding health impact-related publications, 21.4% focused on vector-borne and infectious diseases -such as dengue, malaria, and leptospirosis-followed by respiratory diseases (7.1%), water, sanitation, and hygiene (4.5%). Only 1% focused on the mental health impacts of climate change.

Strengthening climate change education for health professionals is critical to scale research and action regionally.[152] Health professionals are yet to link climate change effects to health outcomes. Furthermore, scientific production in this field is still limited compared to

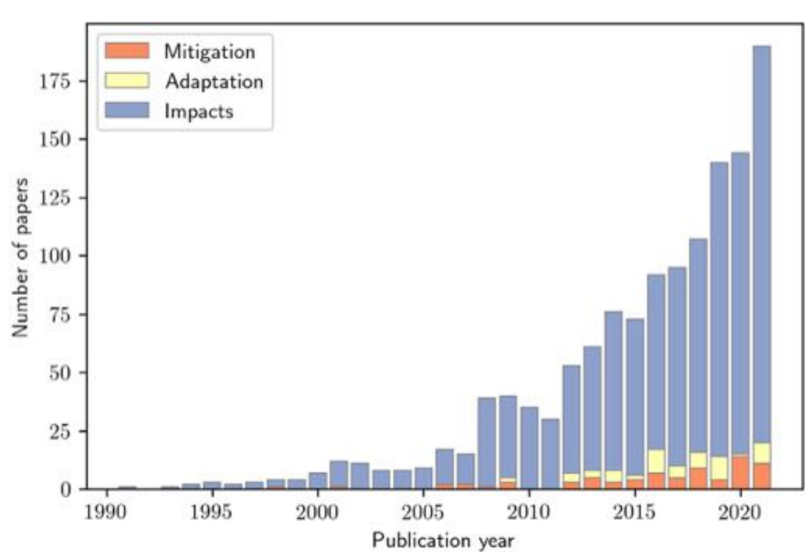

Fig. 11: The number of academic papers published on the nexus of climate and health in SA.

other regions or the Global North.[153] Given the urgent needs and potential benefits of health-centred climate action in the region, local research should focus on addressing the regional research gaps and meeting policymakers' needs.[154] In particular, there is an urgent need to increase research on the health co-benefits and health impacts of mitigation and adaptation measures in SA. This can help guide decisions tailored to local populations and maximise health gains.[155]

Indicator 5.3: government engagement in health and climate change—headline finding: in 2021, the proportion of countries referring to the association between health and climate change increased in the 2021 UN General Assembly (to 58%), and in updated NDC submissions the proportion of sentences that mentioned health terms increased by 396.87%

Governmental action is needed to halt GHG emissions, to maximise the health co-benefits of mitigation interventions, and to implement adaptation strategies designed to minimise the health impacts of climate change. This requires strong engagement of government leaders on health and climate change.

This indicator draws from the 2022 global *Lancet* Countdown report and monitors governmental engagement on climate change and health through two components. Its first component tracks the mentions of climate change-related and of health-related terms in statements made by national leaders at the UN General Debate (UNGD), in which governments communicate their political priorities. The second component monitors the inclusion of health terms in the first or updated NDCs submissions of South American countries, in which countries lay out their self-determined commitments towards delivering the collective commitments laid out in the Paris Agreement. Analysis of both first and updated NDCs submissions provides an indication of the changing prioritisation of health and climate-related priorities over time. The health-related search terms considered for the analysis of NDCs includes health, disease, and illness, death, malnutrition, medical, and injury.

In 2021, seven national leaders mentioned the intersection of health and climate change in the UNGD, an increase from 2020's mentions (four countries). On the other hand, countries like Brazil, Ecuador, Paraguay, Uruguay, and Venezuela did not mention the health and climate change nexus during their interventions. In total, 26 individual references address health and climate change. Argentina is the country that leads health and climate change engagement with seven mentions, followed by Chile and Colombia, with five individual references at the UNGD.

The analysis of the first NDCs includes all 12 South American countries. Ecuador, Guyana, and Uruguay have not yet presented their updated NDCs, and Bolivia presented their updated NDC submission after the period of data collection was finalised, (as of March 2022). Hence, the analysis of the update NDCs submission includes eight South American countries. The percentage of change in the number of mentions of health-related terms from the first to the updated NDC submission was 396.87% The countries with the greatest number of health mentions in the updated submissions were Colombia, Paraguay, and Venezuela, accounting for 87% of all mentions across the eight countries.

Additional analyses examined specific health-related terms, their mention in sections of NDCs (e.g., context, adaptation, impacts, mitigation, finance, executive report). Additionally, the inclusion of gender-related terms was tracked, to monitor engagement and awareness of the gender inequities linked to the impacts of climate change, and of climate action. The results show that, although publication of the updated NDCs submission mostly happened during the COVID-19 pandemic, COVID-19 was only mentioned seven times in 3 s round NDC reports. Health terms are most frequently mentioned in the adaptation sections of NDCs. Across both rounds of reports, this section contains 118 sentences with health-related terms, which is 4.53 times higher in the context section, the second section with the highest frequency of these keywords. Finally, gender was mentioned only twice in first round NDCs and four times in the second round.

Despite government engagement in health and climate change is becoming more pronounced in the region, with health and climate change being more prominent at the 2021 UNGD debate and in the updated NDCs submissions compared to first round reports, it still represents a relatively minor topic. This suggests that the acute threat that climate change represents for health, and the enormous health opportunities of climate action, are still not being adequately acknowledged by the ones in charge of devising a response to climate change.

Indicator 5.4: corporate sector engagement in health and climate change—headline finding: in 2021, engagement among South American companies in health and climate change reached its highest level since 2011, with 33% of companies referring to the health dimensions of climate change in their 2021 UN Global Compact Communication of Progress reports

Corporations can play a key role in curbing global emissions, reducing local pollution, and improving health outcomes. Transnational corporations have the potential to play a leading role as stewards of the biosphere.[156] Within this context, many corporations have voluntarily signed up to the UN Global Compact to demonstrate their commitment to sustainability and social and environmental responsibility.

This indicator tracks mentions of health-related terms in the Global Compact Communication of

Progress (GCCOP) reports in ten South American countries considering corporate engagement across all sectors (Guyana and Suriname data were not available and data for Venezuela were missing for 2011 and 2014). Bolivia, Uruguay, and Venezuela include fewer than 10 corporations on average across the timeframe of analysis, so the indicator reports only regional trends.

The number of companies submitting GCCOP reports has increased from a low of 317 in 2011 to a high of 756 in 2021, a 138% change. The indicator shows that most South American companies mention climate change and almost all of them mention health in their reports. However, most reports refer to health (663 [88%] of 756 reports in 2021) and climate change (499 [66%] reports in 2021) as separate topics. But although a smaller number of reports referred to the intersection of health and climate change (252 [33%] in 2021), this proportion represents a large increase from 2015, the lowest point of engagement, when only 11% of corporations referred to the intersection between health and climate change. It also represents a sixth consecutive year of incremental growth since 2015.

Non-equity investment instruments (75%), household goods and home consumer goods (52%), industrial metals and mining (51%), and equity investment instruments (50%) are the sectors with the highest proportion of reports discussing the intersection of health and climate change in SA. Only 8% of GCCOP reports made mentions of gender in the intersection of health and climate change. More gender representation in the report would be important for South American women, since it could incentivize more women participation and leadership in business contributing to Sustainable Development Goals.[157]

While the increased corporate engagement in health and climate change is positive, this indicator reflects how only a minority of corporations engage in this crucial link, which suggests the need for more engagement in the future by this group of key stakeholders. Moreover, concerns exist about the effectiveness of the UN Global Compact, and the true intentions of sustainability actions that might transcend greenwashed claims. For this engagement to be meaningful, corporations must step up to the challenge, delivering real, meaningful, and rapid reduction in their own direct and induced GHG emissions.

Conclusion

Engagement of multiple stakeholders, with the health dimensions of climate change, particularly governments, corporations, news media, the scientific community, and citizenry, is paramount to generate demand for action that is commensurate to the risks and opportunities, acceptance of climate interventions, and prevent and lessen current and projected health impacts. In this regard, public opinion plays a key role in influencing policy decision making.[162] Engagement with the health dimensions of climate change has increased in SA across news media, science, national governments, and corporations. News media coverage, scientific production, and corporate engagement reached their highest level in 2021. Governmental engagement also saw its peak between 2019 and 2022, compared to one previous measure (first NDCs). Despite the progress, the level of engagement still does not match the magnitude of the challenge. The intersection of health and climate change represents a small proportion of news coverage of climate change, adaptation-focused scientific research, NDC reports, and a minority of corporations' mention such an intersection in their reports to the UN Global Compact. The indicators used to measure public and governmental engagement represent a first step in understanding the South American context. However, the lack of specific public engagement information from different contexts -urban/rural and indigenous peoples and gender intersectionality- undermines the capacity to understand the priorities and perceptions of key sectors of society. Access to information, especially for specific groups, is a key steppingstone towards reducing social inequities and empowering the most neglected population into action. The current four indicators will be improved to better capture public engagement in the region.

Panel 5: Public engagement with the health dimensions of climate change.

Measuring public engagement is paramount to understanding how people interact with the crucially important health and climate change issues. However, quantifying public engagement presents unique challenges due to cultural and regional differences inherently linked to how the general public engages with these issues. Moreover, public engagement can also be present in multiple approaches, from direct action such as pacific protests and civil engagement[158] to online participation in social media platforms or petitions and behavioural shifts such as using non-motorized transportation.[159] Tracking public engagement on health and climate change in SA could include monitoring online interactions—specifically in the context of social media. Currently, Facebook is the most used platform in the region, with approximately 360 million subscribers representing over 80% of the population in the region.[160] Past research suggests online activism is a factor that increases the chances of offline protests in the region.[161]

Conclusion of the 2022 South America report of the *Lancet* Countdown on health and climate change

This inaugural report of the LCSA tracks 25 health and climate change indicators for 12 countries of the South American region. This first report of the *Lancet* Countdown focuses on systematically tracking the health effects of climate change in SA and the region's response level. Still, there remains much to do. As the LCSA team expands, researchers from other academic institutions and disciplines in the region are invited to join the team, expanding the understanding and insights into the health implications of climate change in SA. Following the global *Lancet* Countdown's approach, indicators will be iteratively refined on an annual basis. This will include the use of new and improved databases and methodologies, and wherever necessary incorporating new indicators to cover key topics identified by each of the workstreams of the LCSA.

The health hazards from climate change affecting SA include rising temperatures, more frequent and intense heatwaves and wildfires, lower crop yields, and increased exposure to climate-sensitive diseases. And these are only those risks that have thus far been identified. In the last ten years, there was an increase of 12.3 million person-days of heatwave exposure in older adults above 65 in SA, an increase in heat-related mortality of 160%, economic losses associated with the mortality are equivalent to the average income of 485,000 local workers. SA also experienced a sharp increase in climate suitability for dengue, a disease that entails a major public health concern in the region, with a 35.3% increase for all countries except Chile. Countries like Peru and Ecuador show the highest variability regarding this indicator in close association with "El Niño" events that must be understood as a potential added risk to that posed by climate change alone. Although the entire population will be affected to some degree, those households already living in poverty or under current duress are more vulnerable, less resilient, and therefore more affected by these and other health risks.

Thus far, awareness of the quantifiable health effects of climate change on the South American populations is limited among policy makers and the general public. Even in cases in which the knowledge existed, action has not been proportional to the threats and opportunities. Most countries in SA are not delivering an adaptation response proportionate to the now known risks. On the one hand, we see that several NDCs have included health in their new iterations; however, Brazil is the only that have developed an HNAP up to 2020, allocated the appropriate funds to implement them, or carried out climate and health risk assessments -national and city level-to generate accurate data for evidence-based decision-making regarding health and climate change. In the NAPs, adaptation-related funding dedicated to health adaptation is still not enough. And while several NDCs have included health in their new iterations, action is too slow, if existent at all. Specific climate change mitigation strategies -that could bring massive health co-benefits- are not yet being implemented in the region. This delay contributes to thousands of deaths related to indoor and ambient $PM_{2.5}$ pollution, and to carbon intensive and unhealthy diets across the region. The delay also continues to perpetuate, and even exacerbate, the profound inequities between urban and rural areas.

The slow progress in action on health and climate change is reflected by meagre levels of engagement with these interconnected topics by key actors in society. Engagement and coverage of health and climate change in the media-which is crucial to promote change at the individual and at the political level-is still too low. SA has one of the lowest engagement levels in the world.

Overall, the health trends and regional response observed in this report are grim and of genuine concern. The report highlights the immediate health threats, the lack of health adaptation plans, and the inadequate funding allocated in the different countries to confront the burden of climate change. SA must vamp its effort to create resilient health systems and prepare to change its future. Its current trajectory of climate inaction will only lead to more inequality, poverty, and vulnerability. The LCSA calls on local governments to build a concerted response and define clear pathways to address the challenges that are about to come. SA governments must carry out tangible mitigation strategies to secure one of the world's most significant carbon sinks, while focusing on concrete adaptation measures for the highest climate-related risks in our region, and ultimately improve the health and wellbeing of local populations. The message from the 28 researchers that make the LCSA is clear. Trust de Science: Now that we know, we must act.

Contributors

The 2022 South America Report of the *Lancet* Countdown on health and climate change is an academic collaboration which builds on the work of the *Lancet* Countdown. The work of this paper follows the Global structure of five working groups, which were responsible for the design, drafting and review of their individual indicators and sections.

All authors contributed to the overall paper structure and concepts and provided input and expertise to their relevant sections. Authors contributing to Working Group 1: AGL, YKP, EF, TSC, RS. Authors contribution to Working Group 2: ASI, ZM, DB, NG, FC, MYG, SH. Working Group 3: DRR, SH, RS, TSC, NM. Working Group 4: OM, JH, CP, LO, and Working Group 5: BT, CGP, MS, MFS, MC, SJ. SH, MYG, LBV, DB, AVV, MR provided coordination, strategic direction, and editorial support.

Data sharing statement

Data will be made available from the corresponding author upon reasonable request.

Editor's note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

Declaration of interests

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Appendix A. Supplementary data

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ANEXO 6

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Highlights

- The Latin American Deep Decarbonization Pathways project (DDPLAC) included teams from Argentina, Colombia, Costa Rica, Ecuador, Mexico & Peru
- DDPLAC's purpose was to create energy & AFOLU modelling capability, net-zero DDP scenarios, a community, and initiate stakeholder engagement
- Electricity generation, personal transport, and AFOLU were identified as key areas given current emissions and potential growth.
- DDPs were established for the energy system for Argentina, Colombia, Costa Rica, Ecuador, and Mexico, with initial explorations of AFOLU
- A more in-depth AFOLU DDP was established for Peru
- Mitigation pathways were identified for personal transport and electricity generation.
- Services, buildings, households, and some industry were largely decarbonized through electrification.

- There were significant remaining emissions in AFOLU, freight, industry, oil and gas production and waste, key areas for future effort.
- Areas for research were identified for domestic policy package formation and international cooperation to implement the DDPs.

Abstract

This synthesis paper presents the objectives, approach and cross-cutting results of the Latin American Deep Decarbonization Pathways project (DDPLAC). It synthesizes and compares detailed national and sectoral deep decarbonization pathways (DDPs) to 2050 compatible with the Paris Agreement objectives and domestic development priorities in Argentina, Colombia, Costa Rica, Ecuador, Mexico and Peru. The first five countries analysed in detail the energy system and agriculture, forestry and land use (AFOLU) at a high level, while Peru focussed on a detailed analysis of AFOLU given its predominance in its GHG emissions. While economy-wide results were produced, this paper focuses on the electricity, passenger transport, and AFOLU results because of their current emissions, potential to grow, and identification of successful strategies for decarbonization (e.g. switching to clean electricity and switching to other net-zero fuels across the economy; urban planning, mode shifting, and electrification in passenger transport; and intensive sustainable agriculture, assignment of land use rights and their enforcement and afforestation in AFOLU). It also highlights where significant emissions remain in 2050, notably in industry, AFOLU, freight, and oil and gas production, all areas for future research. It also derives insights for the design of domestic policy packages and identifies priorities for international cooperation. This analysis provides critical information for Long-Term Strategies, Nationally Determined Contributions and Global Stocktaking in the context of the Paris Agreement.

1 Introduction

The Paris Agreement established an objective to hold the increase in the global average temperature "to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C" (Article 2.1). This requires net-zero global energy and land-use CO_2 emissions by the second half of the century (Article 4.1), specifically by 2050-2070 for 1.5-2°C [1,2], and probably net-negative emissions thereafter. Deep targets also apply to all the greenhouse gases; CH_4 and black carbon must fall by half or more by 2050, and N_2O by at least a third. The Paris Agreement also highlights that these emission reductions must be implemented "in the context of sustainable development and efforts to eradicate poverty" and "in the light of different national circumstances". This means that net-zero deep decarbonization must be aligned with each nation's development priorities, i.e. economy wide and sectoral climate policy must be designed to maximize synergies with other objectives such as energy security, clean growth, employment, poverty alleviation, access to energy, local air and water quality, and other goals [3,4,37]. This also means that net-zero deep decarbonization can be reached only through country-specific strategies taking into account national opportunities and challenges

The core strategies of net-zero deep decarbonization are well known: reduce non-welfare enhancing demand, improve energy and material efficiency, decarbonize energy carriers and material inputs and switch end uses to them, and direct GHG reductions through land use and technical negative emissions processes [5–10]. But the challenge is to define country-driven strategies implementing these broad transformations, in a way consistent with national circumstances.

Net-zero deep decarbonization does not necessarily mean every country must reach full GHG neutrality. It does require, however, that each region and sector's emissions trajectory be guided by the goal of carbon neutrality. Some regions and sectors may not go to zero, but this would imply that other regions and sectors go net-negative to compensate for them. From a scenario design perspective, this means going beyond optimization under a carbon constraint and instead focusing on the assessment of maximum feasible action in each sector and the identification of key country-driven transformations to achieve these emission reductions or sink enhancements.

We also know that aligning national, regional and sectoral emissions with net-zero deep decarbonization is not only about how much is reduced in the short term, but how deep reductions are enabled for all sectors by mid-century through fundamental transformations to energy and material use in buildings, transport and industry, and use of agricultural, urban, and other lands [3,5,11,12]. In contrast to the historical approach of doing cheaper reductions first, net-zero requires selecting short-term actions that pave the way for the long term technical, institutional and behavioural changes needed for all sectors to go to close to zero or negative emissions [13]. This requires taking into account path dependencies, inertia and risks or lock-ins related to the time it takes to commercialize new technologies, for them to replace existing stock, to build supply networks for new energy carriers, to develop new buildings and transport infrastructure, to shift land-use patterns, and to shift energy using behaviours. This requires strategic thinking based on a long-term horizon in order to inform short-term decisions aligned with the requirements of these transformations, as per Art 4.19 of the Paris Agreement.

The Deep Decarbonization Pathways (DDP) method [4] articulates a process for designing country-driven visions of these inter-related sectoral transformations, helping guide implementation. The DDP method is based on: backcasting from the net-zero emissions target to the present to articulate short and long-run actions and policies to implement the sectoral transformations; recognition of the inextricable relationship between development and emissions goals to investigate synergies and risks of trade-offs; the need to describe detailed physical transformations for each sector that can speak to stakeholders and sectoral experts; and the identification of possible bifurcations to design robust strategies in a context of deep uncertainty.

The DDP method was used in the pre-Paris Agreement period for 16 industrialized and emerging countries representing 74% of global energy-related CO_2 emissions [5,6]. This original DDP started mostly with experienced modelling teams, focused primarily on energy supply and combustion emissions[1], and was envisaged as a "proof of concept" research project without structured country engagement. Every one of the 16 teams approached engagement differently, from treating it as an academic exercise to full engagement with decision makers and affected stakeholders to help change national policy.

The Deep Decarbonization Pathways Project in Latin America and the Caribbean (DDPLAC) builds on this first experience to investigate how six LAC countries (Argentina, Colombia, Costa Rica, Ecuador, Mexico

[1] Only the Indonesian team [33], and to a certain extent the Australian [34] and Brazilian teams [35], did fulsome analyses of agriculture, forestry and land use emissions, commonly referred to as AFOLU

and Peru) can increase their standard of living and develop while reducing net CO_2 emissions to net-zero by mid to late century, with appropriate reductions for other GHGs [36]. Emissions per capita without waste and AFOLU currently range between 1.6-4.5 tonnes CO_2 per capita, while including waste and AFOLU drives the divergences to 2.2 to 7.6 tonnes CO_2e per capita. In these six countries, the share of emissions from transport (27-70%) are higher than the global average (25%), buildings emissions (3-19%) are below the global average (14%) in most countries, while electricity and industry emissions as a whole are around the global average. There are wide divergences between the emissions from the electricity systems of our LAC countries (from 13 (Costa Rica) to 527 (Mexico) grams CO_2/kWh in 2015), depending on regional access to resources like hydropower.

Table 1 Estimated 2015 GHGs: Combustion & industrial process CO_2 (Mt)

Energy Supply & Demand, & Industry Process CO_2									
Country	Pop.	Passenger Trans.	Freight Trans.	Electricity	Res. Buildings	Comm. Buildings (Services)	Industry (Comb. & Process)	Total	CO_2 per capita
World Mean		25%		21%	14%		40%		
Costa Rica	4.8	3.5	1.9	0.2	0.2	0.1	2.0	7.7	1.60
		45%	25%	2%	2%	1%	26%	100%	
Ecuador	16.3	6.9	5.2	8.1	3.2	1.0	14.4	38.8	2.38
		18%	13%	21%	8%	3%	37%	100%	
Colombia	47.0	14.5	14.0	16.9	7.0	1.5	41.3	95.1	2.02
		15%	15%	18%	7%	2%	43%	100%	
Argentina	43.1	29.2	19.5	39.1	26.3	4.7	48.5	167.3	3.88
		17%	12%	23%	16%	3%	29%	100%	
Peru '15 BUR	31.0	15.8		0.0	3.0		28.1	46.9	1.51
		34%		0%	6%		60%	100%	
Mexico	121.0	106.3	35.6	137.6	19.5	5.9	239.0	543.9	4.50
		20%	7%	25%	4%	1%	44%	100%	

Compared to the first DDPP project, the DDPLAC takes a broader approach to four specific goals :

1. The building of energy and emissions models where they did not previously exist to allow the establishment of domestic capacities for analysis of emissions and development goals.
2. The building of a regional modelling community of practice where one did not previously exist, in order to facilitate knowledge sharing across countries and the bottom-up emergence of a regional approach to the deep decarbonization challenge.
3. The formation and modelling of qualitative narrative and quantitative scenario reference cases, Nationally Determined Contributions (NDCs) and Deep Decarbonization Pathways (DDPs), covering the most important emissions sources (See Table 1 & Table 2).
4. Using these capacities, approach and results to conduct a structured and sustained engagement with policymakers and stakeholders for purpose of informing domestic climate policy processes,

their Long-Term Strategies (Art 4.19) and eventually revised NDCs (Art 4.3 and 4.9) to the Paris Agreement.

Table 2 Estimated waste, agriculture, LULUCF and Total GHGs (CO_2e)

Waste, Agriculture, Forest and Land Use GHGs							
	Waste (CH_4)	Agriculture (N_2O & CH_4)	LULUCF mainly CO2	Total non-combustion GHG emissions	Total GHG emissions	Total non-CO2 GHGs/capita	Total GHG/ capita
Costa Rica	1.9	3.5	-2.4	3.0	10.7	0.6	2.22
	17%	33%	-22%				
Ecuador	2.2	14.3	33.9	16.5	55.2	1.0	3.39
	4%	26%	61%				
Colombia	9.5	45.2	69.0**	123.7	218.9	2.6	4.66
	2.74387	18%	54%				
Argentina	14.9	93.4	50.6	158.9	326.2	3.7	7.57
	5%	29%	16%				
Peru ’15 BUR	7.7	19.0	93.0	119.7	166.5	3.9	5.37
	5%	11%	56%				
Mexico	45.9	94.0	-140.0*	-9.1	534.8	-0.1	4.42
	8%	17%	-26%				

*Includes standing forest LULUCF absorptions, as opposed to just managed lands. Each team chose what AFOLU emissions to report, with the condition of transparency what they reported. ** Includes team estimates of illegal deforestation associated with the end of the Colombian FARC insurrection.

In this paper we describe the synthetic, cross-cutting results of the DDPLAC project. Section 2 will describe the Deep Decarbonization Pathways (DDP) method as applied in this Project. Section 3 will begin with an overall description of the DDP transformation in the collective DDPLAC results, and then discuss the sector by sector transformations. Section 4 will discuss the implications for domestic policy package design and international cooperation. Section 5 concludes.

2 The DDP Pathways Method as applied in LAC

In pursuit of Goals 1 & 2 above, the building and enhancing of both modelling capacity and an analytical community, the DDPLAC project[2] was established as an initiative of the *Inter-American Development Bank* (IADB) with support from the *Agence Française de Développement* (AFD) and the *2050 Pathways Platform* (2050pathways.org), and is coordinated by the *Institut du Développement Durable et des Relations Internationales* (IDDRI.org). Institutions from six countries were chosen to participate: the *Escuela Politecnica Nacional* of Ecuador, *Universidad de Costa Rica, Universidad del Pacifico* in Peru, *Universidad de los Andes* and *Universidad di Rosario* in Colombia, *Tempus Analitica* in Mexico, and *Fundación Bariloche* in Argentina. Given the level of capability from which most of these teams were starting, as per the goal

[2] The DDP-LAC project is financed by the IADB Sustainable Energy and Climate Change Initiative fund (RG-T3028), the IADB French Climate Fund (RG-T3193), the 2050 Pathways Platform, and the *Agence Française de Développement* (AFD).

of the project to establish modelling capacity where it did not yet exist, six institutions were chosen to support the teams: COPPE of the *Universidade Federal do Rio de Janeiro* for the Ecuadorian team, *KTH (The Swedish Royal Institute of Technology)* for the Costa Rican team, the *University of Tennessee* for the Peruvian team, the *University of Maryland Joint Global Change Research Institute (JGCRI)* for the Colombian team, *Evolved Energy* of the US for the Mexican team, and *Centre international de recherche sur l'environnement et le développement* (*CIRED)* of France for the Argentinian team. In aid of goal 2, IADB arranged for four workshops over 2018-2019, facilitated by IDDRI and attended by all the LAC partners and support teams as well as IADB, AFD, and 2050 Pathways representatives. The modelling frameworks built and enhanced by the teams are summarized in Table 3; see the teams' papers in this special issue for details of the modelling frameworks.

Table 3 Model types used by DDPLAC teams

	Model name or family	**Model type**	**Includes energy system?**	**Includes AFOLU?**	**Includes global linkages?**
Colombia	GCAM	Integrated assessment, multiple market partial equilibrium	Yes	Yes	Yes. Colombia's emissions were set within global 1.5 and 2C emissions runs from GCAM.
Mexico	Pathways	Simulation	Yes	Sometimes	No
Peru	POLYSYS	Partial equilibrium	No, other modelling results used	Yes, primary focus	No
Ecuador	MESSAGE "ELENA"	Integrated assessment, optimization, partial equilibrium	Yes	Yes, dynamically balanced with the energy system: demands for useful energy and food and forest deforestation and reforestation scenarios are exogenously calculated	No, but elements can be incorporated from the Brazilian COFFEE model, such as the 1.5°C carbon budget that was used.
Costa Rica	OSeMOSYS	Energy System Optimization Model	Yes	Added outside model for this project. The team is expanding the model to capture the synergies of the energy sector with climate, land, and water to produce the CLEW model	No
Argentina	IMACLIM & LEAP	Hybrid CGE/Simulation	Yes	Added outside model	Non-energy imports to production share and exports elastic to the terms of trade. Global growth trend for non-energy exports. Exogenous energy trade from LEAP

The choice of model used in each region came from a combination of the capability to do a 1.5-2°C compatible DDP for the topics and sectors of interest (e.g. macroeconomic restructuring, transport, electricity or AFOLU) [14] and pre-existing relationships with mentor teams. The Colombian team chose GCAM and its support team because of its capability to explore the nexus between the energy system, AFOLU and water. The Mexican team chose Pathways because of its focus on exploring deep, transformative net-zero decarbonization across all sectors in a North American context. The Ecuadorian model, ELENA, was built from the ground-up using Ecuadorian data, but templated on a Brazilian MESSAGE model, partly due to the large MESSAGE support community and the lead modeller's long relationship with the Brazilian mentor team. The Costs Rican team chose OSeMOSYS partly because of its modular nature, allowing it build on existing electricity modelling capacity. The Argentinian team specifically chose the hybrid CGE IMACLIM because of their desire to explore a DDP involving deep macroeconomic structural change. There was no judgment about the "best" model for a given region, just a pragmatic decision combining scientific relevance of the collaboration given the key policy questions to be addressed and the practicalities for establishing the collaboration given past relationships

Goal 3, the modelling of scenarios to represent "climate policy free" reference cases, the outcome of NDCs, and deep decarbonization pathways was enabled by the model building in Goal 2. The NDCs were modelled as stated out to 2030. For the DDPs, as per Waisman et al (2019) [4], each team was asked to prepare a political economy narrative of how their country may eventually reach net-zero emissions from where they are today, formulated in a qualitative or semi-quantitative manner and speaking the language of key stakeholders. Each narrative discussed where emissions come from today, on what end-use or sectoral demands they are based on, and described how each of passenger and freight transport, residential and commercial buildings, industry, agriculture and land use might transform towards achieving the goal of eventual net-zero emissions. They then simulated these narratives in their models to translate them into quantitative indicators.

Key to the process, based mostly on outputs from their models, each of the teams was asked to fill in a common "dashboard" for each of their scenarios, thereby providing a quantitative representation of the "storyline" for each of their narratives above. The 2015–2050 dashboard indicators included country-wide indicators for population, economic structure, energy system emissions, and land use CO_2 flows, and for each of the economic sub-sectors as many of the Kaya identity components as the teams were able to provide: activity, energy efficiency/intensity, structural change, and GHG intensity of energy. Where relevant, emissions of non-CO_2 gases were also requested (CH4, N2O, SF6, etc.). The dashboards also incorporated additional sectoral indicators highlighting the main changes in key measurable drivers describing the physical transformations in personal transport, electricity and AFOLU, which are discussed in later sections. The team narratives, the outcomes in GHG emissions per capita, the driving activity, efficiency and intensity variables, and the sector specific descriptions of physical driver changes all come together to describe the country DDP scenario .

A key design point of the DDP pathways methodology is its iterative nature, supported by two learning processes. On the one hand, the dashboard results could be compared by the country teams against initial benchmark national and sectoral emission drivers compatible with the collective climate objective. These benchmarks, derived from the literature, characterize the scale and detail of transformative change required by 2050 to achieve the objective of net-zero emissions in the second half of the century. On the other hand, the common dashboard enables the comparison of assumptions across countries and learning about the possibility of different actions (see Goal 2). These two learning processes led the teams to progressively revise their strategy and scenario assumptions, notably regarding technical potentials for decarbonisation in the different sectors. More specifically, at the fourth workshop a seminar was held comparing and contrasting draft economy wide and sectoral DDP results from all the teams. The teams could then see where their results stood compared to the other teams in terms of tonnes per capita and driving variables by sector, and reassess where the differences made sense or not. They then had the opportunity to re-simulate their DDPs. The resulting pathways presented in this synthesis paper and in the country specific team papers of this special issue are the final outcomes of these iterations. They constitute a self-assessment by in-country researchers of what physical sector transformations can be chosen to put the domestic economy on track with the net-zero emissions objective.

In pursuit of goal 4, engagement with policymakers, IADB took the lead in reaching out to local ministries and to introduce the local teams to these ministries if this relationship did not previously exist. The engagement process focussed on establishing awareness of the DDPLAC's usefulness for informing long-term low carbon development strategies and potentially updating the nations' pre-COP 21 NDCs.

3 Modelling Results

3.1 Estimates of nationwide NDCs and DDPs

Figure 1 Projected combustion and AFOLU NDC and DDP CO_2 emissions per capita

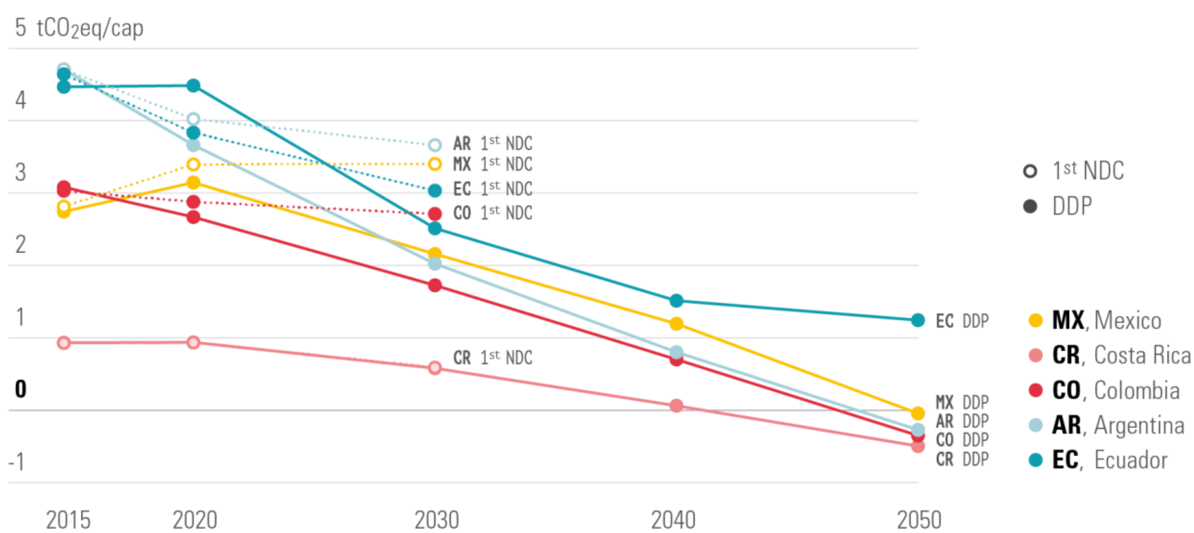


Figure 1 combines the DDPLAC teams' estimates of combined economy-wide combustion and AFOLU CO_2 emissions per capita for both their countries' NDCs as of late 2019 and one of their Deep Decarbonization Pathway (DDP) scenarios. Each team produced between one and four DDP scenarios to represent uncertainties important to their country, as suggested in Waisman et al (2019), and were asked to select one for cross comparison. The Peruvian team did not provide an NDC forecast for energy combustion emissions. Due to space limitations, we have presented the most ambitious DDP scenario for each team except for Argentina, which discusses their most ambitious pathway in their special issue paper because they wanted to provide more context for it. We encourage the reader to visit the country team papers in this special issue for more discussion of the deep decarbonization strategies and their quantitative results.

A wide body of research has shown that the current global set of NDCs allow too many emissions to meet the 1.5 to 2°C goal [15–17], which requires global net-zero CO_2 emissions by 2050-'70 (and gas specific reductions for the other GHGs), and are likely to lead to warming of roughly +3°C. In Latin America it is also the case that NDCs of major emitter countries are not aligned with the Paris goals [18], and our results support this result. Figure 1 shows the NDCs for the country teams that provided them as dotted lines, and the DDPs as continuous lines; most of the NDCs are roughly 1/3 too high to be Paris compatible, unless drastic reductions or very large scale AFOLU or technological negative emissions were employed in later years. All of the Latin American countries' NDCs are subject to ratcheting over the next few years; can these countries use this opportunity to lay out plans to both increase their standard of living and develop while reducing net CO_2 emissions to net-zero by mid to late century? What is involved on a sector by sector basis?

3.1.1 Development & Decoupling: GDP per capita & GHGs per unit GDP

The individual DDP country narratives were purposefully structured to meet development as well as emissions goals, with reference in the various country narratives to GDP per capita, energy supply security, air and water quality, macroeconomic stability, public welfare, basic education, and for the population to be transitioned from subsistence to formal employment. Most of the countries experience fairly strong economic growth while combustion GHGs per unit GDP fall roughly 80% in most cases (Figure 2); strong economic growth was predicated in most cases to support development priorities. We refer the reader to the individual country papers for the narratives, but the overall quantitative results indicate that GDP can be largely decoupled from GHG emissions over time in developing country environments. The physical pathways for this are energy efficiency, demand adjustment and restructuring, decarbonization of energy carriers and switching to them, and direct reductions through land use and in some cases biomass with carbon capture and storage; sectoral results are shown in later sections. There is a large difference in the long term growth per capita in the DDPs of the various countries, with the Ecuadorian economy growing 50% per capita by 2050 from 2015 (1.2%/yr), Costa Rica 74% (1.6%/yr), Argentina 93% (1.9%/yr), Mexico 124% (2.3%/yr), Peru 171% (2.9%/yr), and Colombia 177% (2.9%/yr). One alternative Argentinian scenario (while not shown here, it can be found in their special issue paper), based on a return to long run macroeconomic stability, domestically driven growth, and economic restructuring to "upvalue" the economy, showed GDP per capita growing 3.7%/yr to equivalence with 2050 low European levels, assuming continued historic growth rates in Europe. There was some debate between the teams on the utility of "conservative" versus "ambitious" narratives. The former reflects macroeconomic reality in LAC today, represented by the Ecuadorian scenario, and the latter would reflect LAC after a generation of political and macroeconomic stability and consequent fast growth in productivity, represented most strongly by the Colombian and Peruvian scenarios. In all cases, however, decoupling of GHGs from GDP is demonstrated.

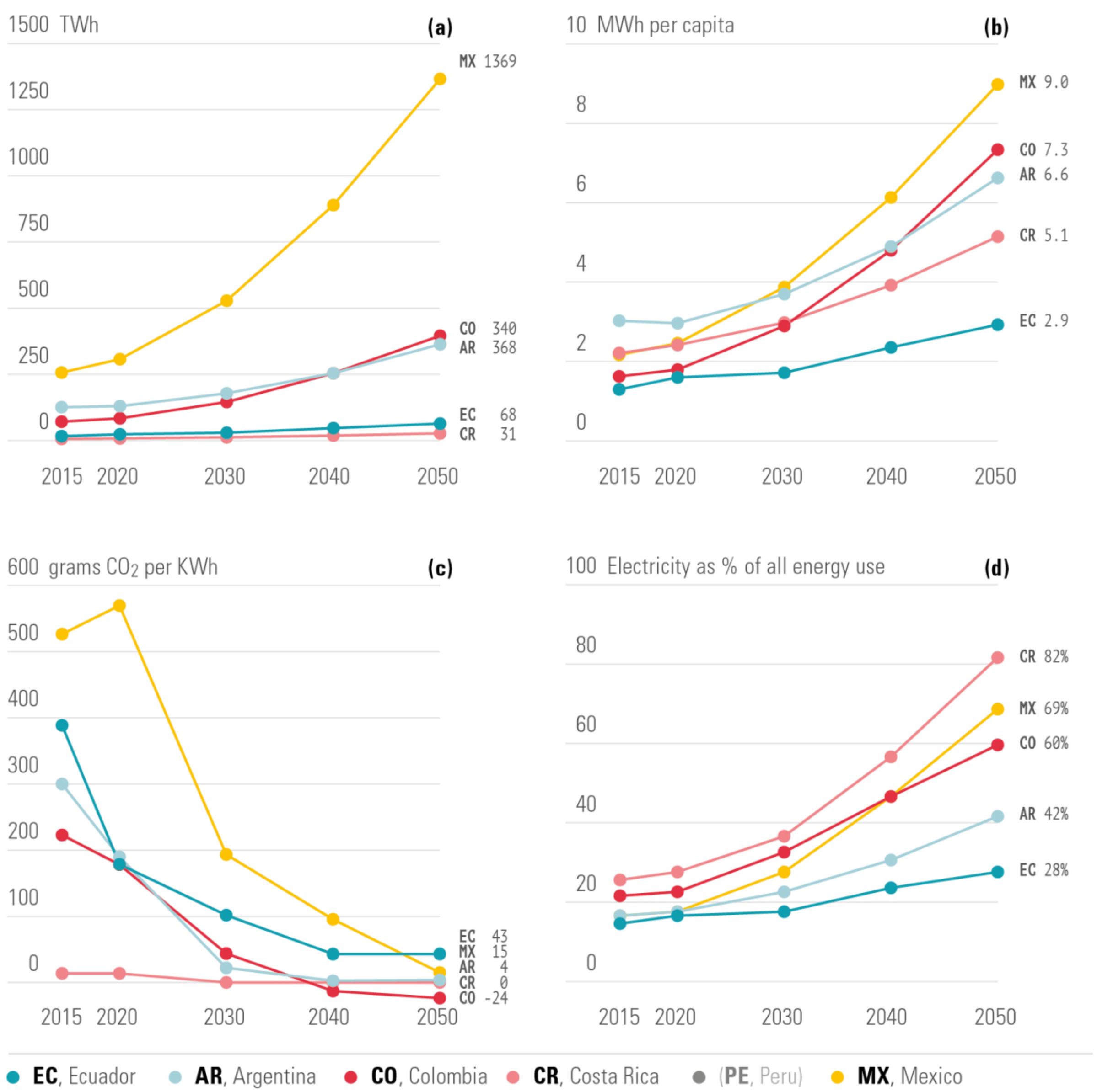
Figure 2 Index of GDP (2015=1) (a) and GDP per capita (b), USD \$2010 per capita (c) and index of combustion CO_2/unit GDP (2015=1) (d)

3.1.2 Sectoral results

The DDPLAC teams produced detailed results for passenger and freight transport, residential and commercial buildings, light and heavy industry, electric power generation, liquid fuel supply and agriculture, forestry and land use GHG fluxes. For reasons of space and because of the predominance of these emissions in an NDC and DDP world, we focus here on electricity, passenger transport and AFOLU.

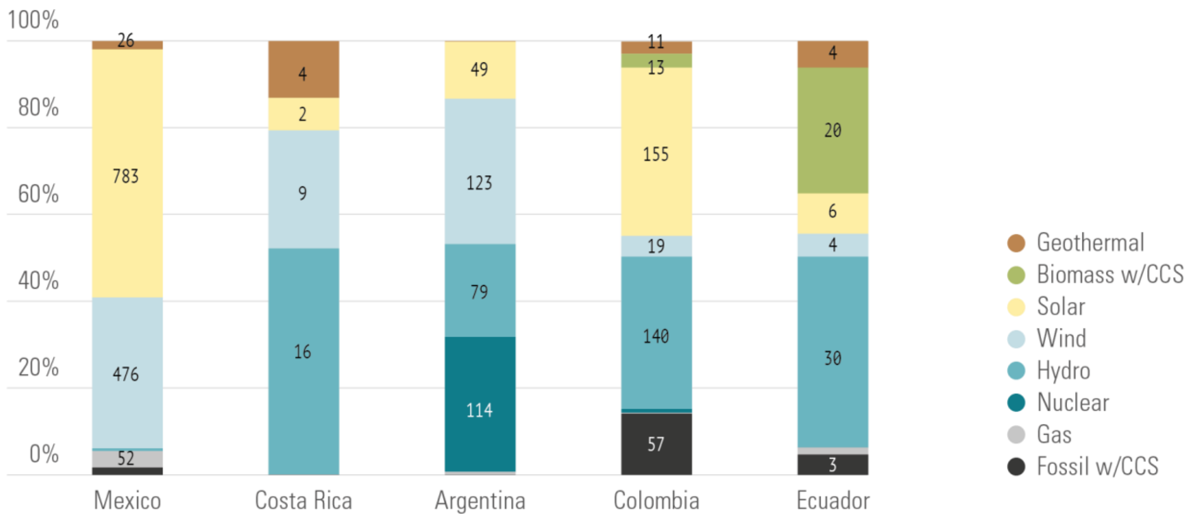
3.1.2.1 Electricity

Figure 3 Total electricity generation in TWh (a), MWh per capita (2015=1) (b), GHG intensity in grams CO_2/kWh (c), as % of all final energy use (d)



Common amongst all the DDPs for all our country team pathways was an economy wide move to electrification of buildings, vehicles and industry combined with decarbonization of electricity production. Electricity as a portion of final end use rose from 15-26% in 2015 to 28-82% by 2050; the differences rest on the relative use of electricity to replace liquid fuels for passenger and freight transport. Electricity generation increased 182-428% by 2050 to meet development needs and to allow the transport, buildings and industrial sectors to decarbonize by electrifying. Ecuador, Argentina, and Costa Rica increased electricity output 182-227%. In contrast Mexico and Colombia increased electricity output 425-428%; there was broader and deeper electrification in the latter two countries, mainly from increased use in freight and industry, both directly and as synthetic electro-fuels. Costa Rica reaches the highest rate of electrification, but from the highest starting point. At the same time GHG intensity of *electricity falls strongly, from an average 405 to 7 grams CO_2/kwh across the region. Every country, however, achieved this reduction differently (Figure 4), with different mixes of wind, solar, hydro, fossil fuels with CCS, biomass with CCS in Ecuador and Colombia, and nuclear in the case of Argentina, which has a small domestic nuclear industry already. Notably, each region is assumed to have relatively inexpensive access to low CO_2 intensity firm power resources (e.g. hydro, biomass, fossil or biomass fuels with CCS, nuclear), to support high variable renewables penetration at a relatively low cost per kWh.[19]*

Figure 4 Electricity generation mix by country in 2050 (TWh)



3.1.2.2 Passenger transport

A comparison of passenger transport emissions per capita highlight that the DDPs of Mexico, Costa Rica, Columbia, Argentina and Peru successfully implement decarbonization, while the DDP of Ecuador shows transport emissions initially falling by half and then starting to increase from 2040 (See Figure 5). The Ecuadorian team noted this was because transport demand per capita increases faster than GHG intensity reductions in the DDP scenario used for the comparison, highlighting the need for international cooperation to reset global passenger transportation technology to zero end-use emissions through electrification or hydrogen fuel cells as fast as possible.

Figure 5 Per capita transport emissions

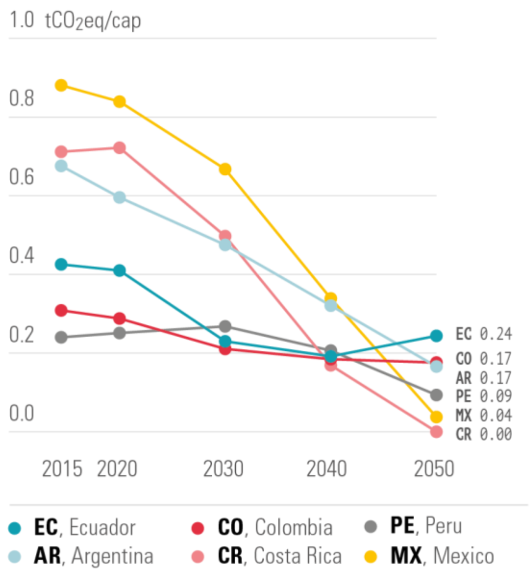
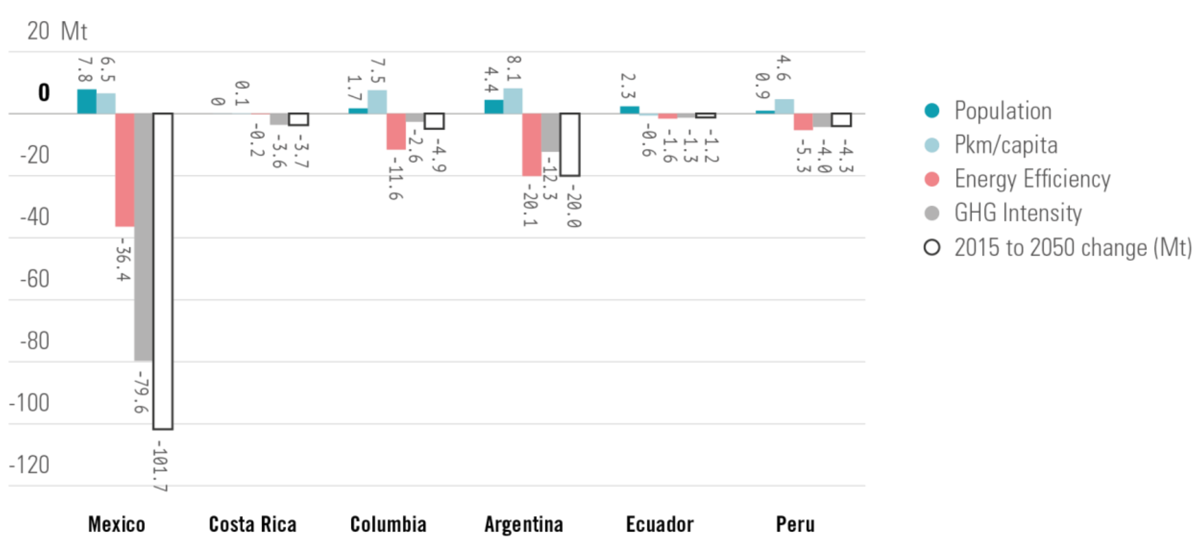


Figure 6 decomposes the changes in an integrated way using an LMDI decomposition [20,21] (See LMDI Methodology Appendix) of the effects of population, passenger kilometres travelled per capita, energy efficiency, and fuel GHG intensity. As expected, population always increases emissions (-15% of total changes in emissions), as does pkm/capita (-24%"). Energy efficiency improvements always reduce emissions (60%"), as does fuel GHG intensity (78%").

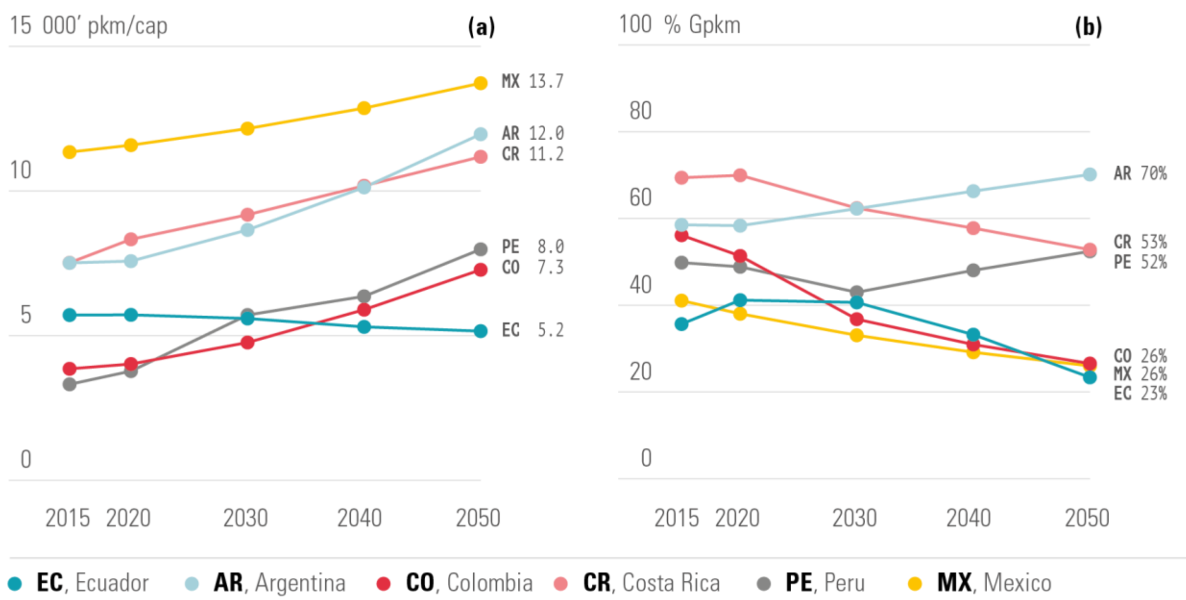
Figure 6 Changes in tonnes Mt CO_2 per year in 2050 compared to 2015 in passenger transport emissions due to population, pkm/capita, energy efficiency and end-use fuel GHG intensity



In order to form policy to reduce emissions in the passenger transport sector, or any sector for that matter, the key drivers must be isolated and directly addressed. Total GHG emissions in passenger transport are a function of distance travelled, the vehicle occupancy rate, how efficient the vehicle is, and the fuel used, all of which are affected by mode choices.

The motorized distance travelled per capita increases in most of the DDP scenarios, but at different rates (See Figure 7). Countries like Colombia and Ecuador with a low-starting value in 2015 experience large increases of 89% and 140% by 2050, while countries like Costa Rica and Argentina with a high-starting value in 2015 experience a moderate growth of 49%-59% by 2050. The Mexican DDP demonstrated a slower growth of 21%, while the Ecuadorian DDP showed a reduction of 10% by 2050 compared to 2015. In spite of their slower growth, Mexico still reaches the highest motorized distance travelled per capita (13 753 pkm), while Ecuador demonstrates the smallest level at 5 170 pkm.

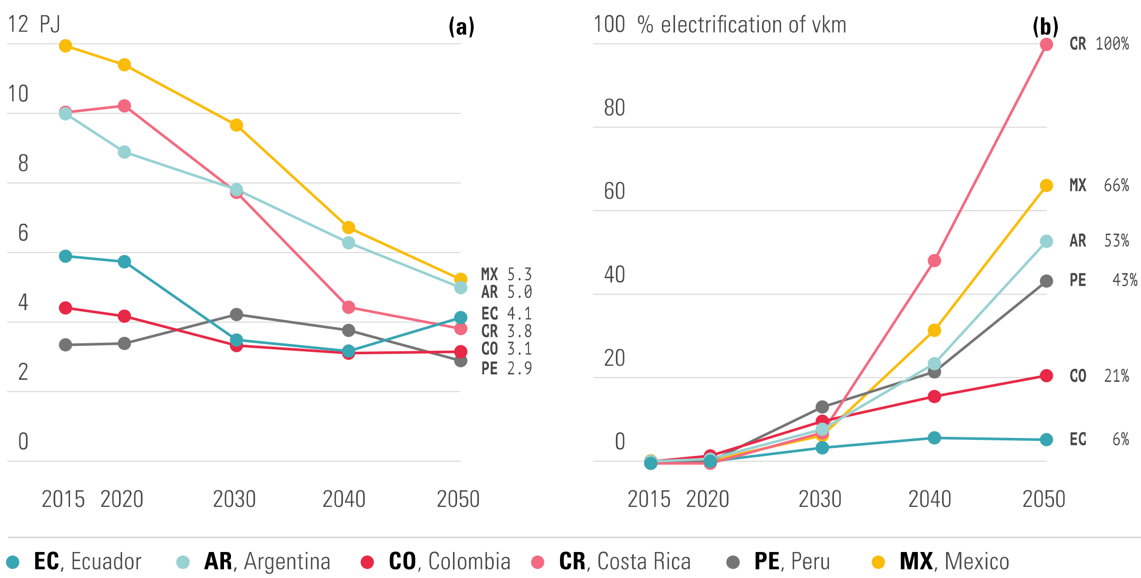
Figure 7 Motorized distance travelled per capita (pkm/cap) (a) and motorized individual mobility (Car + two-wheel vehicle) share (% Gpkm) (b)



However, the role of motorized individual mobility (done by car or two-wheel vehicle) changes in the various DDPs; see the second panel in Figure 7. The results from four DDPs, including Mexico, Ecuador, Costa Rica and Colombia, indicate that the reduction of the modal share of cars and two-wheel vehicles in favour of more collective transport is a key pathway towards deep decarbonization. In Costa Rica, the share of motorized individual mobility decreases from 70% in 2015 to 50% in 2050. The DDPs for the other three countries show the modal share of cars and 2 wheelers falling from 35-55% in 2015 to 25% in 2050. All the above transformations are the result of structural changes in urban areas driven by land-use and urban planning strategies to reduce distances and time between human activities, the development of efficient, affordable, safe and comfortable public transport, and behavioural changes towards local activities and tele-activities. In contrast, in Peru and Argentina, the place of motorized individual mobility is estimated to increase to 52% and 70% of their national total mobility. This is due to a large increase of two-wheel mobility in Peru (+400%) and a large increase of car mobility in Argentina (+170%). In these cases, as for all remaining vehicle kilometres travelled, eventual fuel switching to electric, hydrogen or bio/synthetic fuels would be mandatory.

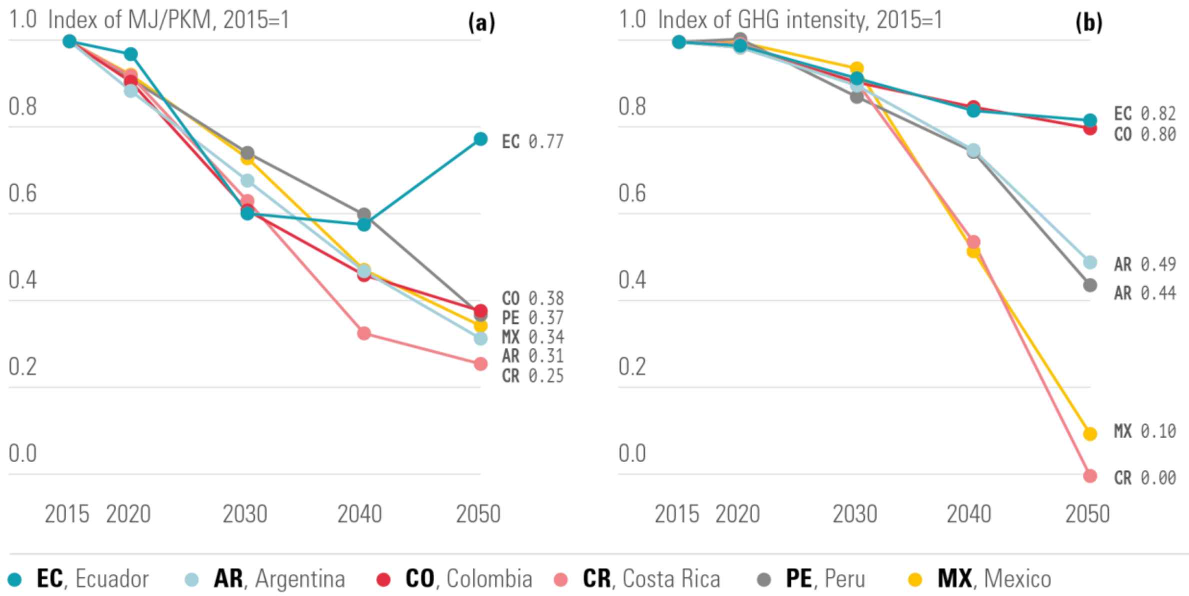
Total energy use per capita in passenger transport falls considerably in all the DDPs from 2015 to 2050, despite large improvements in living standards. Passenger transport energy use per capita falls -14% in Peru, -29% in Colombia, -30% in Ecuador, -50% in Argentina, -56% in Mexico, and 62% in Costa Rica. It falls the most when the share of electricity used in final energy consumption is the highest; electrification of vehicles inherently improves their end use (GJ per km) energy intensity. Electrification of final transport energy consumption reaches 6% in Ecuador, 21% in Colombia, 43% in Peru, 53% in Argentina, 66% in Mexico, and 100% in Costa Rica. These differences in results do not necessarily reflect fundamental differences about the countries or modelling methods, but assumptions about cost and availability of various low emissions technologies. While all the countries adopt some level of mode shifting to urban electric buses, there are widely varying results for personal cars and intercity transport. (Fig. 8). This underscores the need to reset international standards and resulting economies of mass production for passenger vehicle technologies to ultra-low emissions levels (i.e. battery electric or hydrogen fuel cell). These technologies have the co-benefit over biofuels of having zero local air pollutant emissions.

Figure 8 Total energy consumption for passenger transport (PJ) (a) and electrification of all vkm (%) over time (MJ/pkm, 2015=1) (b).



In Figure 9 we look at efficiency improvements and fuel GHG intensity. Energy efficiency improves 41-75% across all the countries; Ecuador returns to lower fuel efficiency in later years as an optimization outcome from accelerated growth allowed by AFOLU negative emissions (see later discussion). Fuel GHG intensity (not including electricity) varies between -18% to falling to zero across the regions, with almost all the countries assessed approaching fuel decarbonization differently.

Figure 9 Passenger transport energy efficiency (a) and overall fuel end use GHG intensity (b)



Other specific transformations could be highlighted in the different DDPs, like the role of domestic air mobility, or the roles of liquid biofuels and natural gas. In Ecuador and Peru for example, domestic air mobility represents respectively 10% and 11% of total motorized passenger kilometres in 2050, but 35% and 47% of the total energy consumption of the sector. The Peruvian team estimates biokerosene could eventually replace up to 30% of the aviation liquid fuel requirements, while no aviation biofuels are considered in Ecuador. In Colombia, the consumption of liquid biofuels reaches 29% of final transport energy consumption by 2050; in Argentina, it reaches up to 11% by 2040 before falling to 4% by 2050, being replaced by electrification. In Columbia, this biofuel demand represents 49 PJ of consumption; it would be a significant challenge to ensure sufficient, sustainable production of biofuels for transport and transformation of the land and agriculture sector. Fossil natural gas plays a big role in both Ecuador's DDP and some of Argentina's DDP scenarios, representing respectively about 49% and 22% of the total energy consumption of the sector, yet biogas is not considered. There is considerable scope for wider consideration of lower carbon energy carriers by some of the teams in future work.

3.1.2.3 Other sectors: Residences, commercial services, freight transport

We repeat the decomposition exercise for residential buildings (Figure 10), commercial services (Figure 11), and freight transport (Figure 12). Industry is not analysed as it was not a priority for the teams in this project, but it is discussed in the following section, "Remaining Emissions in 2050". Where a team did not provide values (e.g. the change in residential m^2 per person in Costa Rica), this is incorporated in the decomposition as no change from 2015 to 2050.

Figure 10 Changes in tonnes Mt CO_2 per year in 2050 compared to 2015 in the residential sector due to population, square meters per person, energy efficiency, and end-use fuel GHG intensity

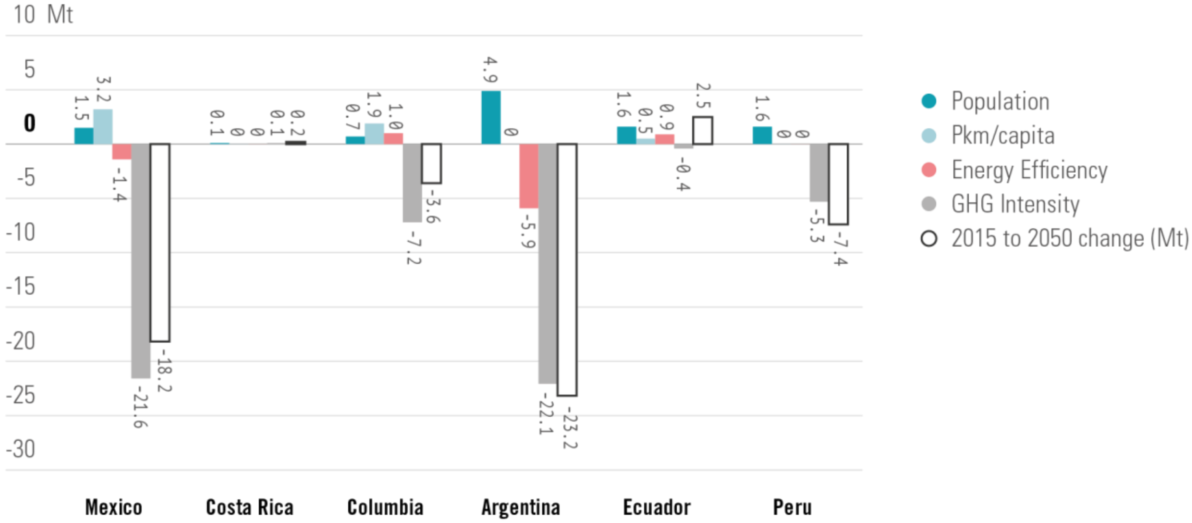
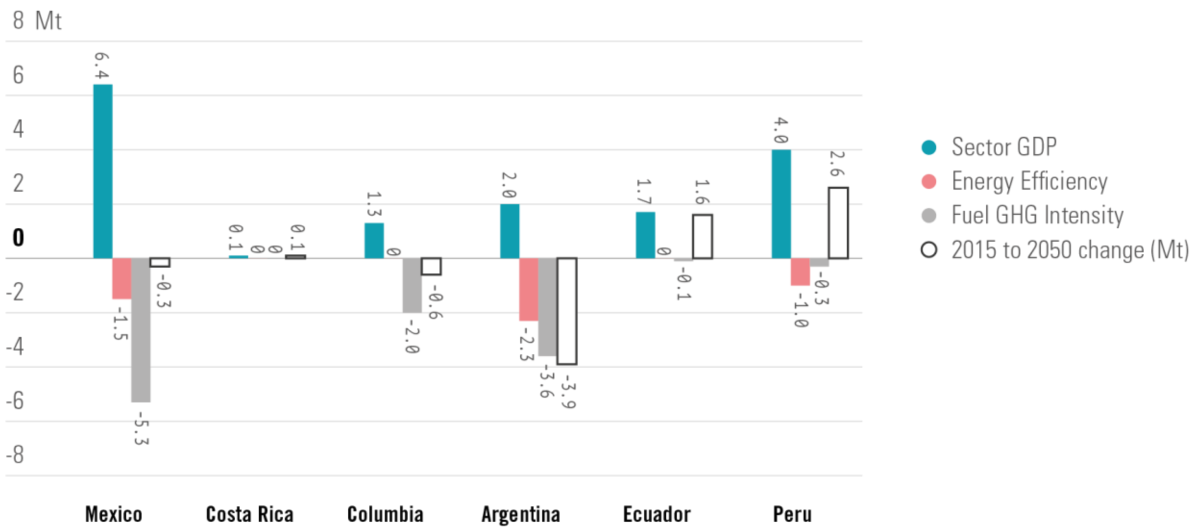


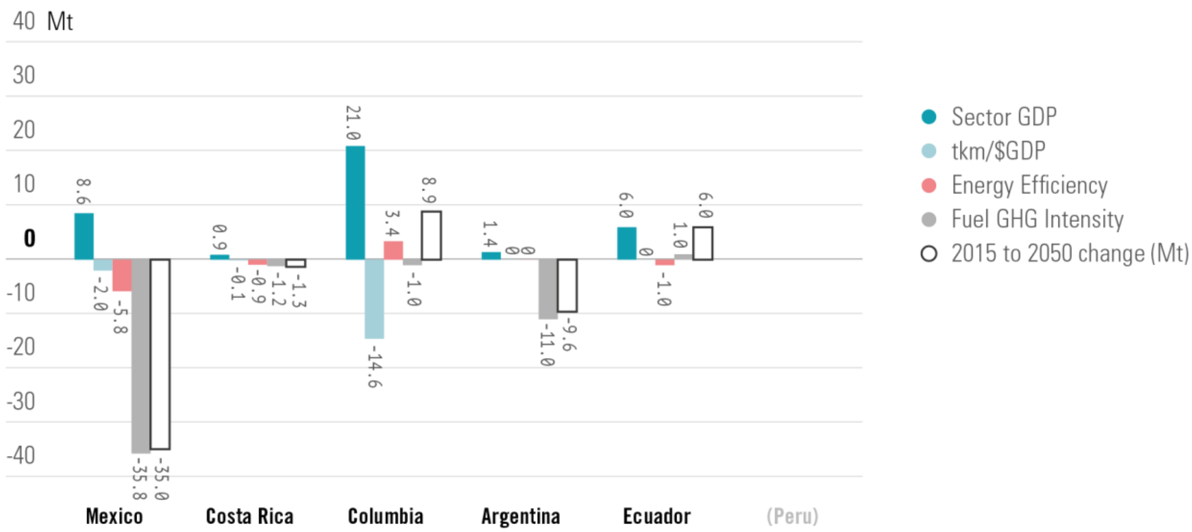
Figure 11 Changes in tonnes Mt CO_2 per year in 2050 compared to 2015 in the services sector due to GDP, energy efficiency and GHG intensity



Population growth always raises emissions going from 2015 to 2050 (+8.7 Mt, or -21% of the total effect on emissions of -42.3 Mt CO_2). Square meters per person (or total households in the case of Argentina) is used as the structure variable and also always increases emisisons (+5.6 Mt, 13% “). Energy efficiency (-5.5 Mt, 13% “) has variable effects, decreasing emissions in Costa Rica, Mexico and Argentina, and raising it in Colombia and Ecuador. GHG intensity falls across all countries, mainly due to fuel switching to electricity (-51.2 Mt, 121%). There are mixed emission dynamics in Costa Rica, Colombia, Ecuador and Peru due to an ongoing shift from GHG neutral biomass cooking and heating to the use of LPG, NG and electricity. This shift has strong indoor air health benefits associated with reduced indoor particulate matter, but counts as increased GHG emissions to the degree LPG or natural gas is used. In the main, reduced GHG intensity of fuels used (e.g. electrification or switching to low carbon liquids and gases) has the largest decarbonization effect.

Sector GDP growth (the activity variable) universally increases service sector emissions (+16.3 Mt, -265% of the total effect on emissions, -6.2 Mt). A structure term was not employed. Energy efficiency mostly decreases emissions (-3.7 Mt, 60%). GHG intensity, primarily due to a switch to electricity from refined petroleum products or natural gas, always reduced emissions (-16.2 Mt, 262%). As for the residential sector, energy carrier switching (electrification and switching to low carbon liquids and gases) has the largest decarbonization effect.

Figure 12 Changes in tonnes Mt CO_2 per year in 2050 compared to 2015 in freight due to overall GDP, tonne kilometres per $GDP, energy efficiency and GHG intensity



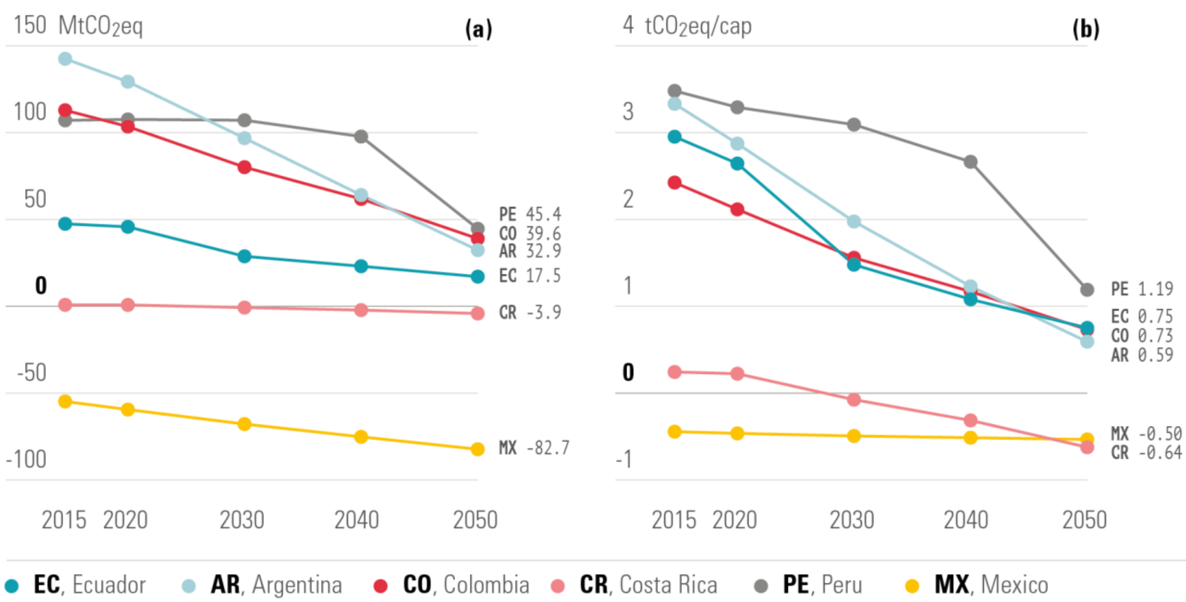
The freight sector showed a wide variety of responses from the teams. Sector GDP is used as the activity variable and always increases emisisons (+30.6 Mt, -97% of the total effect on sector emissions). Tonne kilometers per unit national GDP is used as a structure variable, and generally reduces emission (-15 Mt, 48% “). Energy efficiency’s effect is variable across countries (+0.6 Mt, 2%). Energy efficiency can improve through direct equipment efficiency and internal mode shifting (which is often used as a structure variable, but the data was not available in this case). Finally, fuel GHG intensity is the predominant effect reducing emissions (-48.6 Mt, 154 % “). 80% of this effect is in Mexico, where fuel intensity falls to zero by 2050 based on a moderate modal shift to electric trains and some fuel cell electric trucks. Residual liquid fuel consumption (approx 25% of 2010) is substituted with biofuels and power to synthetic fuels.

A common finding across all three above sectors is the importance of fuel switching to low GHG energy carriers, i.e. electrification and switching to low emission liquids and gases. While national transmission and fuel networks will be required, in many cases these are globally manufactured end-use technologies with common global standards, and international cooperation will be requried for these physical transformations to occur and be affordable in a developing country context.

3.2 AFOLU carbon flows

Decarbonising the AFOLU sector by 2050 will be a challenge given a growing demand for food and increasing or maintaining agricultural exports in most of our LAC countries. All six countries included in this study project AFOLU emissions trajectories that decline from 2015 to 2050; note that AFOLU includes FOLU CO_2 and mainly agricultural CH_4 and N_2O. Mexico is the only country to have net negative emissions in 2015, based on inclusion of net carbon flows into previously degraded forestry and agricultural lands (-55 Mt/yr in 2015), with the negative flux increasing to -83 Mt/yr by 2050. Costa Rica's emissions decline the most over the period, by 436%, and they reach negative emissions between 2020 and 2030. Costa Rica has a long track history of progress in this area, having returned forest cover from 26% in 1983 to 52% today. As for Argentina, Colombia, Ecuador, and Peru, their emissions fall significantly (between 58% in the case of Peru and 77% in the case of Argentina), and all have net positive emissions from the AFOLU sector in 2050. This section will proceed by analysing emissions from land use change and emissions from agriculture separately.

Figure 13 Agriculture, forestry and land use change emission: absolute (Mt) (a) and tonnes CO_2e per capita (b)

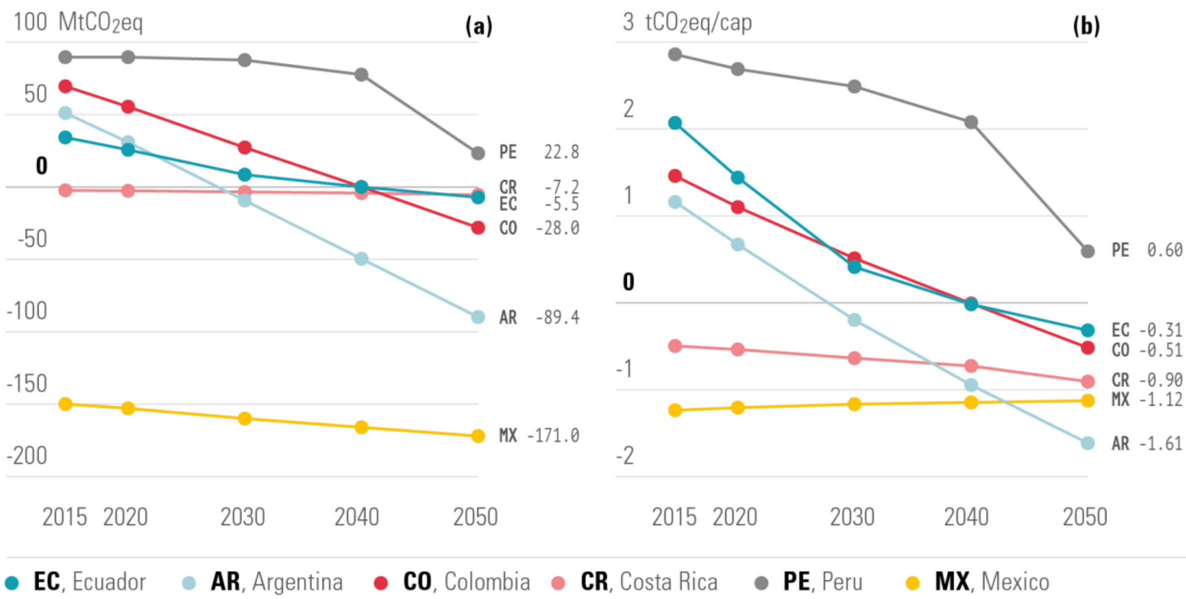


In terms of AFOLU emissions per capita, which makes cross country comparisons possible, all countries have decreasing per capita emissions, with reductions ranging from 0.09 tonnes/capita for Mexico to 3.04 tonnes/capita for Argentina. Peru has the highest per capita emissions throughout the period, going from 3.49 to 1.19 tonnes of GHG emissions per person. Costa Rica, which has the smallest population, have the lowest emissions in 2050, at -0.64 tonnes of GHG emissions per person.

3.2.1 Land Use Change

Regarding land use change (LUC) emissions (Figure 14), which is denominated in CO_2, Mexico and Costa Rica are net sinks in 2015, whereas in 2050, Argentina, Colombia and Ecuador also evolve to having net negative emissions. Mexico stands out as the largest net sink, and sequesters roughly 171 $MtCO_2$ annually in 2050, while Argentina's annual emissions reduce the most over the period (by 140 $MtCO_2$). When interpreting these results one should bear in mind that the Mexican team has included the large annual sink from natural regrowth in previously agricultural or degraded lands. In their paper they include specific discussion of the need to preserve and enhance these sinks, which could potentially make them count as "managed lands" under UNFCC accounting rules.

Figure 14 Land use change emissions by country: absolute (Mt CO_2) (a) & per capita (tonnes CO_2 per person) (b)



Forest deforestation and afforestation (and growth in previously deforested post-agricultural lands in Mexico) are the major negative and positive drivers of land use change GHG emissions. The other land types play a relatively small role because none of the teams included soil carbon, the primary means by which other land types sequester carbon. Forests sequester carbon through the natural growth process of trees and other plants. By the same measure, if the amount of biomass in the forest falls because of wood harvesting, burning, or natural decomposition of dead trees, the forest releases the carbon back into the atmosphere. There are three subcategories of forest emissions (including negative emissions) that occur in the country scenarios: forestland gains, which comprises both afforestation (when land not previously under forest cover becomes forested) and reforestation (when land previously under forest cover becomes forested); forestland loss (deforestation); and forestland remaining forestland (which either gain or lose carbon stocked in biomass). Increased annual sequestration in already existing forests explain the lion's share in both Argentina's and Mexico's negative emissions from LUC. Afforestation or reforestation is also an important contributor to negative emissions in Argentina, Mexico and Peru. The latter, however, has positive emissions from deforestation that overwhelm the negative ones from afforestation or reforestation. Ecuador and Peru are the only countries to project some deforestation, while the other four either do not have information or project zero deforestation. Emissions from deforestation have ceased by 2035 in the case of Ecuador while they remain rather stagnant for Peru.

In Argentina, Ecuador and Mexico, the surface of forestland expands, by 1-4% of the national surface. In all three cases, the prior land use of the afforested or reforested land was primarily grassland used for grazing animals. In Peru and Costa Rica, the forest cover remains stagnant, although there are changes in the cover of other land use types.

The Peruvian special issue paper is one of the few to articulate a policy package to reduce deforestation, increased afforestation and otherwise reduce agriculture emissions. The policy package rests on the idea that forest decarbonization interventions need to induce stakeholders to value the sustainable use and conservation of an ecosystem that took centuries to develop. It rests on five pillars: sustainable forest management; commercial reforestation; rights allocation and enforcement, especially for indigenous populations and sustenance farmers; broad incentives and aid to native communities; and management aid to natural protected areas. The Peruvian policy package also includes measures to increase product diversification, enhance the ongoing process of moving to higher value products, reduce fertilizer intensity , and to introduce dry periods for rice lands to reduce methane formation. Finally, it suggests the use of commercial afforestation, especially to buffer old growth Amazonian forests – this is discussed in more detail in later sections.

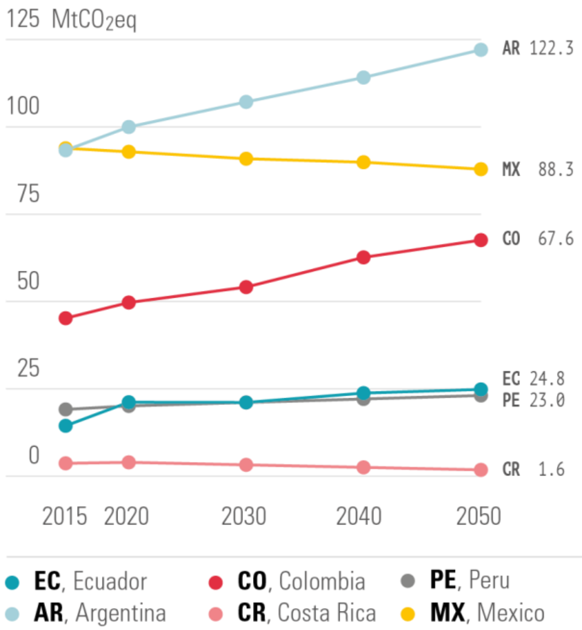
There are some important accounting differences among the countries, which complicates a straightforward comparison. For instance, Argentina and Mexico are the only two countries to account from sequestration in forestland remaining forestland, and this emissions category plays an important role for the total emissions in both of these countries. Colombia, Costa Rica, Ecuador and Peru do not account for this category of negative emissions, which could contribute to explaining the lower negative emissions from those four countries. Another potential difference is the scope of the forest-related emissions taken into account. Peru and Costa Rica are the only countries that take into account sequestration from secondary forests and permanent crops / plantations. They both project the area of primary forests to remain the same. Future analyses could focus on greater reporting consistency, but there are significant political issues associated with land use emissions inventory reporting, e.g. what fluxes can and should countries count and be held accountable for?

3.2.2 Agriculture

All countries face a growing population (16-29%). Growing populations and maintained or increased agricultural exports put a strain on the agricultural sector, which must substantially increase its production to maintain a similar level of food security, lest the country increase its imports of food products or reduce its exports. In some countries, a significant part of the agricultural production is destined for exports, often an important source of income and employment [37].

Total agricultural emissions for each of the DDPs is provided in Figure 15, and is composed of varying mixtures of CH_4 from enteric fermentation, N_2O decay from synthetic fertilizers, CH_4 from rice paddies, and a combination of emissions from other land management practises. Colombia (+50%), Argentina (+31%), Ecuador (+73%) and Peru (+17%) increase their total emissions over the period, while Costa Rica (-53%) and Mexico (-6%) decrease their emissions.

Figure 15 Agricultural emissions, CH_4 and N_2O ($MtCO_2e$)



The major source of agricultural emissions in all countries included in this study is methane from enteric fermentation, which arises from the digestion of fibres in ruminant livestock, primarily cattle. Nitrogen oxide emissions from synthetic fertiliser application also play a key role in many of the countries. Emissions from fertiliser application tend to increase more than emissions from enteric fermentation (EF) in the countries' scenarios. In the case of both Mexico and Argentina emissions from fertilisers increase while those from EF decrease. For Ecuador and Colombia, emissions from fertilisers increase much more than emissions from EF as both sources of emissions increase. Peru, where emissions from fertilisers stagnate whereas emissions from EF increase, is the exception to this tendency. This indicates that in order to decrease AFOLU emissions, emissions from animal production are easier to mitigate than emissions from vegetal production. A parallel tendency in the scenarios of the countries is that livestock herds in most cases remain static, or at least grow by a lower percentage than fertiliser usage, which increases strongly for all countries. More research is required for all the above to ascertain deep decarbonization pathways for agriculture.

3.2.3 Further AFOLU analysis

Putting agricultural emissions in relation to the total production provides another perspective, the emissions intensity of agricultural production, providing indications of the sector's capacity to decarbonise while feeding a growing population and maintaining exports. All countries increase their food production and most of them substantially. Argentina increase theirs the most, and increase crop production by 63% (in tonnes) and animal herds by 46% (in Livestock Units), much of which is exported. Costa Rica has the lowest increases, an 9% increase in crop production and 2% in livestock herds. Importantly, five of the six countries also manage to decrease their emissions per unit of output (both per tonne of crop yields and per livestock unit) – Costa Rica by over 400% (which is possible as their emissions go net negative). The only exception to this is Mexico, which increases its emissions per unit of output.

The increase in agricultural production can in all cases be explained by an intensification of agriculture (i.e. increases in output per unit of land). This intensification is on the one hand illustrated by increases in the yields and increases in the livestock density. All countries except Costa Rica increase their yields drastically, ranging from 43% in the case of Peru to 68% in the case of Ecuador. The livestock density remains static for Mexico and Ecuador, but increases by 24% for Peru and 70% for Costa Rica. Hence, all countries intensify either vegetal or animal production, and two countries (Peru and Argentina) intensify both. The intensification of vegetal production is sustained by an increase in the application of synthetic fertilisers, which increases in all countries except Peru – and in Mexico it more than doubles. On the other hand, the intensification is illustrated by reductions in total land used for agricultural production, which includes both cropland for vegetal production and grassland for grazing animals and production of fodder. Ecuador, Costa Rica and Mexico all decrease the land available for agricultural production, with as much as 17% in the case of Costa Rica. The surface of agricultural lands remain unchanged in Argentina, whereas Peru increase their agricultural land.

By dissecting the AFOLU sector into land use change and agriculture, it is clear that to the extent that countries decarbonise in their scenarios, this is mainly possible through reductions in land use change emissions rather than agricultural emissions (which increase in four out of six countries). One explanation for this could be the growing populations in each country, as discussed above. Another, cited by Argentina, is the capacity to free large tracts of land for afforestation (the same explanation could perhaps be applied to the cases of Ecuador and Mexico, who also afforest or reforest significantly). Interestingly, all countries in this study have chosen to pursue a path that in one way or another intensifies agricultural production, which on the one hand in part relies on emission-intensive activities in agriculture (e.g. fertiliser application), while on the other hand liberates land for afforestation or reforestation and thereby enables emissions reductions. In sum, even with improved agricultural productivity, technology and best sustainable practices, there is a significant trade-off between agriculture, livestocking, forestry, and natural land use sinks .

3.3 Remaining emissions in 2050

Figure 16 indicates the remaining absolute 2050 GHG emissions for each country in the DDP scenarios, which is interesting because it contains both legitimate resistance to mitigation that will require stronger and more creative innovation and policy, and decarbonization pathways as yet unexplored by the teams. Figure 17 translates this into more comparable tonnes CO_2e per capita. While one must be careful in comparing results from countries with very different national circumstances, several things stand out. First is the widely varying nature of AFOLU emissions, which partly reflects the nature of the natural and human influenced fluxes in each country as well as the level of ambition for reducing emissions from this sector; for some teams (Ecuador and Colombia) the energy supply and demand models optimized including AFOLU, in the others it was modelled separately from the energy system. Second is that emissions have been largely squeezed out of electricity, residential buildings, and services; decarbonization pathways are well known for each of these, e.g. reduced fuel GHG intensity through electrification. Varying levels of emissions remain in passenger and freight transport, depending on the degree of urban planning, mode shifting, and vehicle technological options made available in the DDPs, as well as widely varying assumptions about the adoption of biofuels or hydrogen fuel cells. Substantial emissions remain in light and energy intensive industry, which were not a focus of this project, but merit further attention in the future.

Figure 16 Remaining 2050 GHG emissions in the country DDPs, including negative fluxes (Mt/yr)

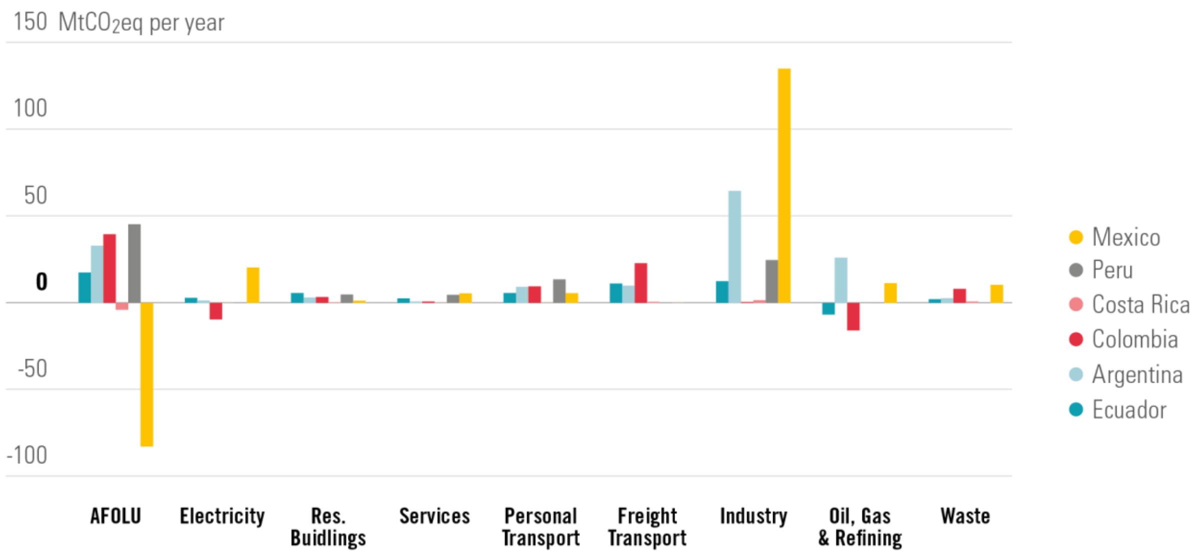
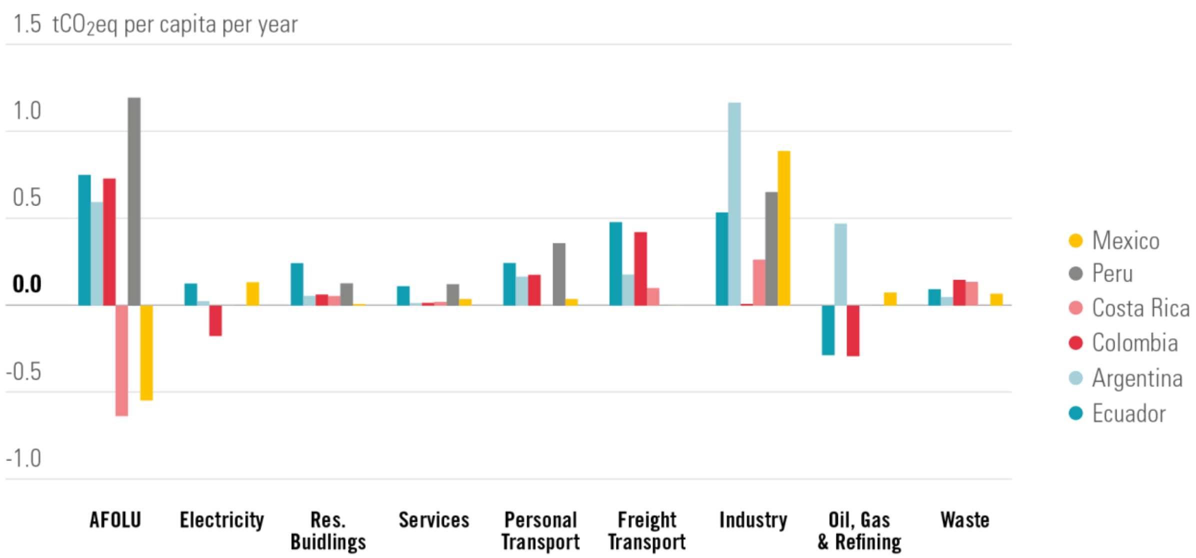


Figure 17 Remaining 2050 emissions by sector per capita (tonne CO_2e per capita per year)



It has been noted in a growing literature that there is a class of "hard(er) to abate" sectors, including freight transport, aviation, steel, cement, chemicals and other heavy industry [8,9,23,24]. These results were repeated in this project as remaining emissions in the country DDPs. Further research could prioritize projection of demand forecasts, likely domestic production, potential material efficiency improvements[25], and how to decarbonize production in these sectors [26–29] in the LAC context. Given remnant light industry emissions, given this sector's capacity for electrification, use of waste or solar heat,

heat pumps, and replacements for natural gas (e.g. biogas or hydrogen), further research is warranted to include these options in the models.

The Colombian and Ecuadorian teams notably used biomass processing and carbon capture and storage to generate negative emissions, while the Ecuadorian team used biomass and carbon capture and storage electricity generation.

A positive outcome from our DDP results are the relatively small remaining oil and gas production and refining emissions. Oil and gas emissions form a large part of current inventories[22] and their relatively small level in the DDPs, which are first analyses for many of our teams, is a welcome development. The scenario used for Argentina has significant gas production; other scenarios produced by the Argentinian team and discussed in their special issue paper do not. Reduced oil and gas revenues will, however, have fiscal implications for several of our LAC countries.

4 Discussion

4.1 Domestic policy package design and international cooperation

The contrast between the first round NDCs and DDPs shows there is a need for government and stakeholder visioning and planning to allow policy package design to move the long run evolution of our LAC countries off a fossil fuel orientated pathway to one heading towards net-zero later this century. While much of the power and capability to do this sits within these countries, the physical nature of the sectoral transformations outlined in our DDPs have shown there is wide scope for international cooperation to reduce GHG emissions to net-zero levels in Latin America, and in developing countries in general.

4.1.1 Transportation

The passenger transportation results for most DDPs showed a largely successful transformation to low carbon transport met through differing mixes of urban planning, mode shifting enabled by infrastructure and transit construction, electrification of buses and passenger vehicles, and alternative net-zero liquid fuels (e.g. sustainable biodiesel and ethanol). About half the DDPs also dealt successfully with freight through electrification, mode switching and alternatives for fossil diesel.

Very large transport investments are already being planned as the LAC countries urbanize and their populations grow. A key policy initiative will be to shift much of that investment to low and zero emissions higher capacity transport and urban planning, rather than lower occupancy gasoline vehicles. While urban planning and infrastructure construction is under control of the national, state and local governments within their management and financial capabilities, some nations and regions may need assistance doing state of the art, higher density, high transit and non-motorized mobility urban planning and infrastructure building. They may also need assistance with concessional "signalling" or "de-risking" capital to help access private capital markets for capital intensive urban transit, e.g. Peru and Lima in particular may need assistance with planning, construction and finance of the Lima metro, which is planned to displace 4 million passenger vehicles.

Full electrification of new buses and private vehicles will require that these technologies become the new regulated norm for transport use; this will only occur if this is so at the global level given the interlinked nature of global transport manufacturing and the necessary economies of scale to make battery and fuel cell vehicles affordable. While electric buses and cars are probably already cheaper than their fossil counterparts on a life cycle basis, and may eventually be cheaper than gasoline and diesel versions on an upfront basis depending what happens with battery costs, they currently cost more to buy. Policy is needed to address this, non-exclusively including low cost finance for bus fleets, targeted and declining subsidies, GHG intensity performance regulations that match global efforts, and building of charging networks.[30] LAC cities may also need aid with guiding the private sector in planning and implementing electricity charging and alternative fuel networks, both for reasons of equity and making sure all parts of cities and eventually countries are covered. Finally, subsidies for transport fossil fuels will have to be reduced and eventually eliminated as fast as domestic politics allow.

Decarbonization of transport, small and large buildings and light industry requires large amounts of clean electricity in our DDPs, which comes from various mixes of wind, solar, hydro, nuclear and biomass with carbon capture and storage**.** Increasing clean electricity output by +182-425% as shown in our DDPs will require efficient, low cost procurement, associated transmission and increased domestic installation capability for all parts of the supply chain. Electricity generation and transmission construction will require clear policy direction for both output and GHG intensity. The output signal can be provided by normal electricity planning and market processes combined with stated government intentions and policies to electrify transport, buildings and light industry. The GHG intensity of generation signal can vary, but will likely be provided by strong and effective regulatory and planning structures orientated towards building mainly low and zero GHG generation and associated transmission, e.g. renewable portfolio standards, or simple requirements that all new generation be very low or zero emissions unless for balancing variable renewables. All the above will require efficient market structures that send appropriate marginal and average pricing signals to consumers and provide the means to amortize the invested capital, whether it be by self-generating households, buildings and industry or by conventional power utilities. Our LAC countries may benefit from assistance from regions and utilities globally that have integrated higher (i.e. >10%) levels of wind and solar while maintaining system stability and reliability, and how to use existing assets (e.g. impoundment hydroelectric dams) and resources to do this.

Transport and energy infrastructure investment, reduction of oil and gas revenues, and reduced subsidies for fossil fuel use will have significant combined municipal, regional and national impacts on government revenues, and net government financial flows must also be considered as part of the national planning process. Long term tax reform towards incentive structures that encourage innovation, employment, investment, and limitation of GHG emissions while maintaining government revenues to provide public goods will need to be considered in the long run. We did not include this tax reform analysis in DDPLAC, but encourage exploration of this dynamic in future work.

AFOLU has perhaps the greatest scope for international cooperation that extends beyond current market and finance based development bank channels. All our participating countries exhibit relatively large fluxes from deforestation, afforestation, and agriculture compared to their populations, and very large potentials to turn the positive fluxes down (e.g. reduce deforestation) and increase negative fluxes (e.g.

increase afforestation, reduce fertilizer use, extend best practises, diversify current mono-cultures, increase soil carbon sinks, etc.). These fluxes are an outcome of the behaviour of millions of individual, family and firm units, many without security of land tenure or the ability to enforce their tenure and use rights, etc., which leads to very short run orientated decision making (e.g. low productivity slash and burn agriculture). Reducing deforestation, increasing afforestation, and other practises to reduce emissions are also made harder by illegal mining, agriculture, and forestry, the end of guerrilla warfare in the case of Colombia (the civil insurrection paradoxically reduced deforestation by denying access land access to those would deforest), and illegal deforestation for cattle, etc. For example, in Brazil deforestation is mainly the sequential outcome of small sharecroppers pushing their cattle into government forest lands to establish “squatters rights”; once these rights are established, they sell the land to larger agricultural firms [31]. Brazil was successful for many years slowing and halting this process using unarmed or lightly armed police; once these police were removed, the process of deforestation resumed. In Ecuador and Peru, deforestation is the outcome of subsistence farmers with insecure or absent tenure resorting to very low productivity slash and burn agriculture, sped up in Ecuador’s case by oil and gas roadmaking into the Amazon. If the skills of these subsistence farmers could be improved, and better paid work available to them, deforestation could slow down. Policies based on establishing and enforcing land tenure (e.g. in Ecuador, Brazil, and Peru) have been successful in the past in reducing deforestation, increasing afforestation, and supporting sustainable efficient agriculture. A careful assessment is needed of how these kinds of policies can be encouraged and supported domestically and internationally, and should be a key focus of future work. Finally, the Peruvian special issue paper noted there is a substantial opportunity, beyond the domestic financial resources of the Peruvian government, for large scale commercial afforestation to induce negative emissions, improve biodiversity, and perhaps most importantly, help stabilize the size of the Amazon at a scale large enough to maintain its unique, self-sustaining hydrological conditions.[32]

The IPCC Special Report on 1.5°C indicates that large, gigatonne scale negative emissions (up to 3.6 GtC per year from land use in 2050, and up to 5.0 GtC per year of biomass with CCS) will be needed from land use and negative emissions technologies, increasing with time[2]. As currently constructed, the international climate policy governance regime provides very little incentive for a country with large carbon fluxes under its management to manage for the global sink. The incentive is very strong to count these fluxes towards the domestic inventory and use them to reduce or slow the need to reduce energy system emissions to net-zero. This has important long-term implications for regions with the capability to go net-negative (e.g. those with significant land use sink potential, such as in Latin America). Do they use it for their own purposes to balance their emissions for growth purposes, or transfer these negative emissions, which will likely be needed for ambitious temperature goals, to a global “fund” within the context of their sovereignty? We do not pretend offer an answer to this conundrum, but instead provide evidence of the importance of providing a robust and effective incentive structure for LAC countries to assign their negative emissions to the global sink, while lowering their energy system emissions to net-zero.

4.2 Lessons for future DDP-like processes

First, the teams very much benefitted from co-reviewing of their results at the fourth workshop in Quito after all their model building and scenario construction. A longer, more iterative approach with more co-review opportunities would likely have been beneficial.

Second, this project was initially meant to be only about energy supply and demand, but the predominance of AFOLU in the national inventories of the LAC nations encouraged some reprioritization to a combination of energy supply and demand and AFOLU emissions. This might have been an easier transition if there had been a longer workshop at the beginning to review regional priorities in a Paris compliant world.

Finally, when taken altogether, the cross-country diversity of country strategies illustrates the breadth of options available to decarbonize. Considering more systematically all the different options in each country context will be a priority next step in our research agenda, both to investigate more robust strategies and to explore possibilities for deeper cuts.

5 Conclusion

The DDPLAC project has shown that pathways can be developed for LAC countries to reach net-zero GHG emissions while benefitting from economic growth, improved air quality, lower cost and higher quality transport, and other benefits. Implementing these pathways will require multipronged, interactive policy packages that address all emissions and development goals, sensitive to the region's needs and circumstances. The results presented in this paper, detailed at a sectoral level and explicit in the content of physical sectoral transformations, can help provide policy-relevant insights for national discussions about the transition and possibly inform these countries' Long Term Strategies, revision of their Nationally Determined Contributions to the UNFCCC, and short and long run policy formation.

6 LMDI Appendix

Our decomposition analysis starts with an identity that accounts four generic factors (overall activity, end-use intensity per unit activity, energy intensity per unit end-use, and fuel GHG intensity per unit energy) that influence CO_2 emissions from fossil fuel consumption (Equation 1).[21]

$$(1)\quad C = \sum\left(Activity \cdot \frac{SectorEU}{Activity} \cdot \frac{Energy}{SectorEU} \cdot \frac{GHG}{Energy}\right) = \sum(A \cdot EU \cdot EE \cdot G)$$

Where:

C = CO_2 emissions

Activity = Activity or sector GDP. We used population in the case of passenger transport and residences (households for Argentina), and GDP for services and freight.

SectorEU = Sectoral end-use demand per unit of overall activity (pkm/pop for passenger transport, sq m^2 per capita for households, tkm/$GDP for freight, none for services)

Energy = Energy consumption by sector end-use demand

GHG = GHG emissions by sector

To compare the CO_2 emissions in 2050 and 2015 Equation 1:

(2) $\Delta C = C_{2050} - C_{2015}$

(3) $\Delta C = \sum(A \cdot EU \cdot EE \cdot G)_{2050} - \sum(A \cdot EU \cdot EE \cdot G)_{2015}$

(4) $\Delta C = \Delta A + \Delta EU + \Delta EE + \Delta G$

Where:

ΔC = Difference in total CO_2 emissions between region *c* and region *m*

$\Delta C_{Activity}$ = Difference due to activity

$\Delta C_{EndUseInt}$ = Difference due to end-use demand per unit of activity, i.e. end-use “intensity”

$\Delta C_{EnergyEff}$ = Difference due to energy demand for each unit of end-use demand

$\Delta C_{FuelGHGInt}$ = Difference due to fuel GHG intensity per unit energy demand

We use the LMDI I approach to calculate the subcomponents of Equation 4 in Equations 5-11 because it is easy to use, robust, and has no residual term (ΔC_{Res} = 0):

(5) $\Delta C_{Activity} = \sum \frac{C_{2050}-C_{2015}}{\ln\left(\frac{C_{2050}}{C_{2015}}\right)} \cdot ln\left(\frac{Activity_{2050}}{Activity_{2015}}\right)$

(6) $\Delta C_{EndUseInt} = \sum \frac{C_{2050}-C_{2015}}{\ln\left(\frac{C_{2050}}{C_{2015}}\right)} \cdot ln\left(\frac{EndUseInt_{2050}}{EndUseInt_{2015}}\right)$

(7) $\Delta C_{EnergyEff} = \sum \frac{C_{2050}-C_{2015}}{\ln\left(\frac{C_{2050}}{C_{2015}}\right)} \cdot ln\left(\frac{EnergyEff_{2050}}{EnergyEff_{2015}}\right)$

(8) $\Delta C_{FuelGHGInt} = \sum \frac{C_{2050}-C_{2015}}{\ln\left(\frac{C_{2050}}{C_{2015}}\right)} \cdot ln\left(\frac{FuelGHGInt_{2050}}{FuelGHGInt_{2015}}\right)$

The first term in each of the equations is the logarithmic mean of the difference in CO_2 emissions between 2015 and 2050. This value is multiplied by the natural log of the ratio of the factor in question, e.g., the ratio of 2015 activity to that of 2050, to calculate the influence of that factor on the difference in CO_2 per capita between the time periods

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ANEXO 7

DEEP DECARBONIZATION PATHWAYS

POLICY LESSONS FROM THE

Deep Decarbonization Pathways in Latin America and the Caribbean Project

OVERALL SYNTHESIS AND COUNTRY TEAM PERSPECTIVES

DDPLAC

DDPLAC Consortium. Edited by C.Bataille

With the support of:
INTER-AMERICAN DEVELOPMENT BANK (IDB)
AGENCE FRANÇAISE DE DÉVELOPPEMENT (AFD)
2050 PATHWAYS PLATFORM

IDDRI

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DEEP DECARBONIZATION PATHWAYS (DDP) INITIATIVE

The DDP initiative is an initiative of the Institute for Sustainable Development and International Relations (IDDRI). It aims to demonstrate how countries can transform their economies by 2050 to reduce their greenhouse gas emissions in a deep and coherent way, with the aim of reaching carbon neutrality as soon as possible in the second half of the 20th century. The DDP initiative is based on the Deep Decarbonization Pathways Project (DDPP), which analysed the deep decarbonisation of energy systems in 16 countries prior to COP 21 (deepdecarbonization.org). Both projects share key principles. Analyses are carried out at the national scale, by national research teams, working independently from their governments. These analyses adopt a long-term time horizon to 2050 to reveal the necessary short-term conditions and actions consistent with the achievement of long-term climate and development objectives. Finally, national research teams openly share their methods, modelling tools, data and the results of their analyses to share knowledge between partners in a very collaborative manner and to facilitate engagement with sectoral experts and decision-makers. The development of long-term deep decarbonisation sectoral trajectories in different countries, in this case with freight transport in France, is part of this broader initiative.

DDPLAC Consortium

The Deep Decarbonization Pathways in Latin America (DDPLAC) consortium is managed by the Institut du Développement Durable et des Relations Internationales (IDDRI). It consists of a group of independent experts in the following institutions

- Fundacion Bariloche, Argentina
- Centre International de recherche sur l'Environnement et le Développement (CIRED)
- Universidad de los Andes, Colombia
- Universidad Del Rosario, Colombia
- Pacific Northwest National Laboratory (PNNL)
- Universidad de Costa Rica, Costa Rica
- KTH Royal Institute of Technology
- Escuela Politecnica Nacional, Ecuador
- COPPE- Uniersidade Federal do Rio de Janeiro (UFRJ)
- Tempus Analitica, Mexico
- Evolved Energy Research
- Universidad del Pacifico, Peru

The views expressed in this report do not necessarily reflect the views of any government or those of the institutions of the different authors.

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POLICY LESSONS FROM THE

DEEP DECARBONIZATION PATHWAYS IN LATIN AMERICA AND THE CARIBBEAN PROJECT

DECEMBER 2020

DDPLAC

CROSS-CUTTING POLICY LESSONS

COUNTRY PERSPECTIVES

ARGENTINA

COLOMBIA

COSTA RICA

ECUADOR

MEXICO

PERU

Graham Watkins
Chief of the Climate Change and Sustainability Division
Inter-American Development Bank

Foreword

The COVID-19 pandemic is still raging across Latin America and the Caribbean with large negative effects on peoples' health, jobs, and liquidity. The medical and social emergency is the focus of governments, but they are also looking to the future and to ensuring sustainable economic recovery.

The pandemic affects our region because of pre-existing development gaps. Informal street vendors, for example, cannot work from home or make money if everyone else works remotely and have limited or no access to health care. The pandemic is hitting 50% of such informal workers in Latin America and the Caribbean especially hard. These same vulnerable groups are most affected by the climate crisis, for instance, when heat waves make it too hot to work outside or storms and floods present life-threatening risks. Our recent book, Jobs in a Net Emissions Future, published with the International Labour Organization, highlights why countries need a plan to recover from the pandemic's economic and social effects while getting on track to create net-zero and climate resilient economies by 2050.

This new report showcases the results of the Deep Decarbonization Pathways for Latin America and the Caribbean project (DDPLAC), which has generated important experience in how development banks can help countries design long-term decarbonization strategies. DDPLAC is an academic project designed and executed by the IDB, in partnership with the 2050 Pathways Platform and the French Development Agency (AFD), that draws upon the knowledge and skills of the Institute for Sustainable Development and International Relations.

In this project, academics and think tanks from six countries have confirmed, through rigorous peer reviewed analysis, that technical solutions exist to transition towards net-zero carbon emissions while preserving economic growth. The analysis shows that decarbonization is possible and can bring social and economic benefits. Renewable energy is now cheaper than fossil fuels. Using public transport, walking, and cycling can reduce demand for private transport and the huge economic cost of congestion. Electrifying transport and other energy uses can reduce deadly air pollution. The intensification of agriculture production, a shift to healthier plant-based diets and a reduction in demand for meat can also help reduce deforestation and protect ecosystems.

The transition to a net-zero emissions economy will challenge the social, political and financial status-quo. Even when zero-carbon solutions are available, existing regulations and market design can prevent the private sector from developing profitable business models around them. In another recent report, Getting to Net-Zero Emissions, we showed that countries need a roadmap to navigate these challenges and transition to a net-zero carbon economy. National institutions typically task the ministry of environment to design climate change plans under the Paris Agreement's Article 4. But implementing such plans will be the responsibility of the private sector and line ministries. It is thus essential that we help ministries of environment to reach out to the other sectors and frame their decarbonization strategies in a way that they can each understand and embrace because it advances their own agenda.

Local academia and think tanks can help the design of multi-sector climate strategies. In Chile, Colombia, Costa Rica, and Peru, we are now supporting discussions with stakeholders from the energy, transport, and agriculture sectors, among others, to discuss what a decarbonization plan should try to achieve. Stakeholders share their priorities, such as supplying cheap energy, reducing congestion and air pollution, improving nourishment indicators or food exports, and building resilience to climate effects. To ensure a just transition, governments should make sure they share the gains from decarbonization, and that they address the losses, for instance, by the workers and communities who today depend on fossil fuel extraction. Numerical simulations are key to quantify how sectoral transformations can reduce greenhouse emissions while achieving these other goals.

Our work in Costa Rica has shown how climate strategies can serve as a roadmap for development and mobilize international finance. Costa Rica's National Decarbonization Plan, built using results from DDPLAC, has over 70 targets for 35 different government agencies and ministries to be carried out by 2023 to kick-start a transition to net-zero emissions by 2050. These include regulatory actions (e.g. the rules on how to set electricity prices in electric vehicle charging stations), investments (e.g. to enable public transit), and studies (e.g. assess options to fund an updated payment for ecosystem services scheme). The IDB and French Development Agency then partnered to support the Plan with a USD 380 million loan, and over eight million in grants.

In sum, our experience supporting countries in the region shows successful approaches for other development banks to consider financing greater climate ambition. First, collaborate with local academic institutions to build their abilities to quantify and inform policy debate around climate. Second, bring together discussion groups to discuss synergies between decarbonization and sectoral development priorities. Third, use technical assistance to build a development strategy that achieves carbon neutrality by around 2050, with a roadmap of regulatory reforms and investments needed to enable the uptake of carbon-free solutions by the private sector. Both investment and policy-based loans and more technical assistance are important to support the plan.

I hope this report will contribute to replicating these successes around the world.

Abstract & project summary

Net-zero CO_2 and large reductions in other GHGs are needed by 2050-'70 to meet the Paris Agreement goals of maintaining +1.5-2°C over preindustrial temperatures. This is technically feasible in Latin America and would have significant air quality, economic and social benefits. The PA, by design, puts countries firmly in charge of how to define and accomplish their contribution to the global net-zero effort, and most of the power to achieve it lies with them. The Long-Term Strategies (LTS) asked for in the Paris Agreement, and the process for creating them, can be helpful for the planning, stakeholder engagement and policy package formation required to deliver the Paris climate goals while meeting other development priorities. From an economy wide point of view, near term 2025-2030 emissions targets and policy need to be realigned with global net-zero emissions by 2050-'70 to guide short-term policy and dissuade investment that locks in GHG emissions. The key physical transformations are: electrification with low GHG electricity of all feasible sectors, including all buildings, light industry, and urban and intercity personal transport; mode shifting in transport nonmotorized transport and high use electric vehicles supported by urban planning; curtailment of most new and existing fossil fuel extraction; and low carbon agricultural intensification combined with reduced deforestation and afforestation. Alternative zero carbon fuels such as hydrogen and biofuels will be required for freight, aviation and parts of heavy industry. All the above will require economy wide and sectoral policies, non-exclusively including reductions in fossil fuel subsidies, general electrification mandates, performance standards, and charging and fuel network building, all of which will require complementary policies. With domestic priorities clear, countries can then see where there are capacity gaps or other areas where international cooperation is both needed and can be more effective. In the short term, to 2025 and mindful of the recovery from COVID, the key activity will be building consensus amongst all stakeholders who will either carry out or be strongly affected by the sectoral changes, and to review existing policy frameworks and regulations for consistency with achieving net zero emissions by 2050-'70.

Project summary

The Deep Decarbonization Pathways in Latin America Project (DDPLAC), which included teams from Argentina, Ecuador, Costa Rica, Colombia, Peru and Mexico, ran from early 2018 through 2020 with the following goals. 1) Building of energy and emissions models where they did not previously exist to allow the establishment of domestic capacities for analysis of emissions and development goals. 2) Building of a regional modelling community of practice where one did not previously exist, in order to facilitate knowledge sharing across countries and the bottom-up emergence of a regional approach to the deep decarbonization challenge. 3) Formation and modelling of qualitative narrative and quantitative scenario reference cases, Nationally Determined Contributions (NDCs) and Deep Decarbonization Pathways (DDPs), covering the most important emissions sources. 4) Using these capacities, approach and results to conduct a structured and sustained engagement with policymakers and stakeholders for purpose of informing domestic climate policy processes, their Long- Term Strategies and eventually revised NDCs to the Paris Agreement. DDPLAC was initiated by the *Inter-American Development Bank (IDB)*, funded by IDB's Sustainable Energy and Climate Initiative, IDB's French Climate Fund, the *Agence Française de Développement (AFD)* and the *2050 Pathways Platform*, and managed by the *Institut du Développement Durable et des Relations Internationales (IDDRI.org).*

CROSS-CUTTING POLICY LESSONS

Chris Bataille
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IDDRI

Executive summary

Net-zero CO_2 and large reductions in other GHGs are needed by 2050-'70 to meet the Paris Agreement goals of maintaining +1.5-2°C over preindustrial temperatures. This implies rapid and far-reaching transitions in energy supply and demand; agriculture and land use; urban form, infrastructure, transport modes and buildings; and industrial systems. Most of the current round of emissions reduction pledges outlined in the Nationally Determined Contributions (NDCs) are insufficiently ambitious to achieve the Paris Agreement goals because of their too high absolute 2025-2030 headline goals, their lack of sectoral detail in terms of the technological and economic structural transformation to be pursued, and absence of goals beyond 2030. For all these reasons the current NDC GHG reduction objectives cannot be translated into specific actions on the ground that can be effectively integrated with development objectives to maximise the benefits of the transition.

Net-zero CO_2 emissions systems transitions consistent with strong economic and social development in Latin America are technically possible, with a primary focus on the following strategies.
1) Produce zero carbon electricity (e.g. large-scale rollout of renewable energy combined with grid flexibility & firm power support measures).
2) Undertake widespread electrification (e.g. using electric vehicles, motors, heat pumps, boilers and cooking stoves), and where not possible, switch to other carbon-free fuels (e.g. hydrogen or sustainably-produced biofuels).
3) Increase the share of public transportation (e.g. bus or train) and non-motorized transportation (e.g. walking and cycling) in total mobility and reduce demand for transport. Finally,
4) encourage lower carbon (e.g. less meat intense) diets, which can help with preserving and regenerating natural carbon sinks (e.g. by reducing cattle related deforestation and promoting reforestation) and restore other carbon-rich ecosystems. All this can be done while increasing the number and quality of jobs and overall well-being.

There are large potential benefits from transitioning to net zero emissions, notably air quality improvements, lower congestion, investment driven macroeconomic acceleration, job creation, improved and preserved ecosystem services, and reduced costs of delayed action (e.g. poorly chosen long lived energy and infrastructure assets that must be scrapped before the end of their functional lifetimes if emissions reduction objectives are to be met). But there are challenges too: fast growing transport and energy needs; challenging land use governance conditions and incentives; current fiscal dependency on coal, oil and gas revenues; and access to finance.

In this regard the Long-Term Strategies (LTS) asked for in the Paris Agreement can be a helpful instrument to inform the creation of more ambitious NDCs. LTS can also support the design of the policy packages required to deliver climate goals and other development priorities. The long-term planning exercise the LTS requires can help anticipate challenges or areas where the transformation to a net-zero future could hurt some areas of society, thus allowing time to envision solutions including through social dialogue. Furthermore, LTS can inform how to maximize development gains, considering technology options and appropriated timeframes for delivery to boost benefits and reduce costs in line with the ultimate target of net zero emissions by 2050. The end goal of an LTS is to create a roadmap for the policy reforms and investment steps needed to reach a decarbonized economy by around 2050. The long-term effects of infrastructure and equipment choices, and the social and economic impacts of transformation policies, need to be carefully anticipated.

The Deep Decarbonization Pathways in Latin America Project (DDPLAC), initiated by the Inter-American Development Bank (IDB), funded by IDB's Sustainable Energy and Climate Initiative, IDB's French Climate Fund, the Agence Française de Développement (AFD) and the 2050 Pathways Platform, and managed by IDDRI, was

designed to help build local capacity to research LTS design grounded on a strong science base and embedded in the national policy dialogue. It brought together academic country teams from Argentina, Colombia, Costa Rica, Ecuador, Mexico, and Peru to: develop energy and land-use modelling capacity, build a modelling community, develop initial NDC estimates and Deep Decarbonization Pathways (DDPs), and start the process of stakeholder engagement, particularly with policy makers, with the goal of helping establish LTS consistent with the Paris Agreement. The following economy-wide and sectoral policy relevant messages emerged from the teams' work.

From an economy wide point of view, near term 2025-2030 emissions targets and policy need to be realigned with global net-zero emissions by 2050-'70 to guide short-term policy and dissuade investment that locks in GHG emissions. Governments can reduce fossil fuel subsidies, reallocate existing fuel excise taxation consistent with fuel carbon intensity, and make finance available for strategic investments such as low GHG electricity and urban transport infrastructure. All sectors should be encouraged to electrify or switch to net-zero emission fuels (e.g. through technology and performance standards and full carbon intensity pricing). Developing an LTS can help identify investment and policy priorities, which can facilitate a more effective over time balance of net government revenues and costs as fossil fuel extraction revenues and fuel consumption subsidies simultaneously decline.

In the short term, to 2025 and mindful of the recovery from COVID, the key activity will be building consensus amongst all stakeholders who will either carry out or be strongly affected by the sectoral changes, and to review existing policy frameworks and regulations for consistency with achieving net zero emissions by 2050-'70. Moving forward to 2030, policy for physical investment in general electrification and clean transport must begin; done right, the transition can bring fifteen million net jobs in the region by 2030 and generate benefits worth several percentage points of GDP just through avoiding the current loss of productivity in congestion and health impacts from pollution, all hopefully speeding the recovery from COVID.

From the point of view of the key sectors studied in our LAC countries, a sincere step towards addressing the climate crisis and limiting the worse of its impacts will require immediate action on the following key areas:

- Given the role of clean electrification for private transport, light industry, residences and commerce, **electricity generation output and GHG intensity must be aligned with the long-term target of net zero emissions by 2050-'70 at the national level, with steps in that direction starting now**. Given the life span of power generation plants this translates into requiring, by policy means appropriate for each country, all new electricity generation to be very low or zero emissions, e.g. solar, wind, closed-loop geothermal, nuclear, clean hydrogen, or fossil fuels with 95+% carbon capture and storage. Other sources with higher emissions, e.g. gas turbines, should only be considered when their express purpose is supporting variable renewables, and there is a long-term plan to transition them to hydrogen or renewable natural gas or replace them with other zero emitting firm power sources. Modern planning and investment for high variable renewables with adequate firm power support must accompany this transition, i.e. 70-80% wind and solar is known to be achievable (40-60% is already being achieved in Europe), but only with good planning, time sensitive end-use price signals, sufficient interties and multi-time interval clean firm power investment. While a transformative change in how the economy is structured and powered, end-use electrification brings very significant local air quality benefits to indoor spaces and congested urban spaces, critical issues in Latin America.
- To meet the goals of the Paris Agreement countries globally will need to phase out their use of coal, oil and gas or use carbon capture and storage by mid-century, imperiling LAC production both for export and domestic use. **New LAC fossil fuel production investment should be curtailed**, **and plans prepared to phase out existing production in a prudent manner, mindful of the impact of the transition on government finances.** Enabling plans to manage fiscal and employment impacts, including tax reform, should be prepared to allow for adaptive policy and contingencies. An LTS can help inform this conversation, which should be

a key short-term priority for policy makers, anticipating challenges and enabling planning ahead for a smoother transition for public finances and jobs.

- National, regional and municipal governments may consider using land use & transit planning to encourage non-motorized, high-occupancy low-emissions travel. A key priority is mandating zero emission motors (battery, fuel cell, or hybrid combinations) for vehicles operating in urban environments as soon as possible, concentrating on high local air polluting buses and trucks first (e.g. Ecuador's requirement that all new buses be electric by 2025). This will require setting standards for charging & fueling networks, building them and financing them, and enabling finance and business models to address the currently higher initial cost of these vehicles.
- Perhaps hardest due to the governance challenges but of vital importance given the relative regional importance of AFOLU GHG emissions (close to half of LAC's emissions) and the biodiversity value of LAC's forests, all levels of government need to help farmers employ sustainable intensive agriculture and assign and enforce land use rights to encourage reduced deforestation, supplemented with commercial afforestation to buffer and expand existing high biodiversity and carbon sink lands. Encouraging a shift to lower carbon diets, i.e. less meat intensive, would reduce deforestation pressures as well. Active participation in international negotiations to create a durable international incentive structure for all countries to maximize their land use sinks is a significant long-term need and enabling condition.

The Paris Agreement, by design, puts countries firmly in the driver's seat of how to define and accomplish their contribution to the global net-zero effort, and most of the power to achieve it lies with them. Most of the necessary technology already exists, especially in transport, buildings and electricity production, is proven, and is rapidly getting cheaper with global economies of scale and innovation. The more countries pull in the same direction at the same time, the faster costs will fall. For most sectors to drive these technologies into the marketplace requires careful policy design and regulation, particularly at the sector level and with consideration of national fiscal policy. With regards to the finance needs for new transport and energy infrastructure, there is sufficient capital and borrowing capacity in the countries; public funds and private money can finance most of it, the challenge will be redirecting existing flows to clean investments and away from high GHG intensity energy infrastructure (coal, oil, gas). With planning, a well-designed LTS can help clarify and prioritize the necessary redirected and marginal investments and policies required. All this, however, will require institutional capacity and strengthened multi-level governance

With domestic priorities clear, countries can then see where there are capacity gaps or other areas where international cooperation is both needed and can be more effective. The most obvious is a collective effort to commercialize or bring down the cost of key technologies, and to make them available to all who need them, e.g. energy storage; low cost clean hydrogen; key industrial technologies for steel, cement, chemicals, mining, etc. Countries may also need guidance on policy instrument design for high renewable electricity system planning, growth and stabilization. Another key area is mobilization of resources to reduce deforestation and increase afforestation. In some instances this is a matter of domestic political will, enforcement of existing rules, and establishment of new land use rights, especially for indigenous peoples, but in others international capital to pay for (or at least value) large scale commercial afforestation would enable forest protection and afforestation programs that are beyond the resources and intrinsic motivation of domestic governments and actors.

To identify pathways to domestic action and the LTS, and what will be needed from coordinated global action, an ongoing dialogue will be required with all those stakeholders who must implement the transition or are otherwise strongly affected by it. Neither the LTS nor short-term policy package formation built on it can be "one-off" exercises; as stakeholders begin to adapt, technologies evolve and new information in general becomes available, the national plan and derivative policy package will need to be revised and revisited.

While the above results are largely consistent across the six countries, there are some country specific results to note. Please note that many of these points also apply to various degrees to our other countries and societies globally.

Argentina

- Unique in Latin America, Argentina has the capacity for a domestic nuclear power industry as an option for firm clean electricity to support variable renewables, but this requires a focussed energy strategy to achieve.
- There is a currently a strong commitment to developing Argentina's Vaca Muerta gas reserves, but this make sense in a low carbon world only if carbon capture and utilization and storage is fully developed at a reasonable cost.
- Amongst its deep decarbonization pathways, the Argentine team developed a unique scenario where Argentina reaches a per capita standard of living comparable with Europe by 2050 and net zero decarbonization through economic restructuring and "upvaluing" from its current export commodities focus.
- Because of Argentina's large methane emissions from cattle under all scenarios (methane emissions need to fall by 50% by 2050 under the IPCC 1.5°C Special Report scenarios), reaching GHG emissions consistent with 1.5° to 2°C requires a focussed effort to reduce deforestation and to do significant levels of afforestation.

Colombia

- The Colombian team highly emphasized that controlling deforestation, which rose after the peace agreement with FARC allowed access to more of the country, is key for lowering its emissions.
- The Colombian team also found that the distinction between CO_2 and non-CO_2 GHG gases (the IPCC 1.5°C Special Report requires roughly -1/2 CH_4 and -1/3 N_2O emissions, both key agricultural GHGs) are important in the context of countries such as Colombia, where the agricultural sector is economically relevant, both currently and as an engine for future growth. Demand side diet changes and reduced fertilizer use have been identified as key to addressing agricultural GHGS. Agricultural emissions are only modestly reduced across their three scenarios, as the sector must provide for food, intermediate, and energy demand in a context in which international trade is important. Domestic policies, international cooperation, consumer awareness and farmer education are all needed to directly address these emissions.

Costa Rica

- Costa Rica is one of the most advanced countries in the world in terms of net-zero decarbonization stakeholder engagement, planning, and policy package formation, as it corresponds with both its existing and aspirational economic structure (tourism and high value agriculture based on biodiversity) and its development challenges (transport congestion and urban air quality challenges).
- Costa Rica is also a model for dealing with land use carbon sinks, having increased forest cover from <30% in the 1980s to almost 60% today, partly to encourage its tourism trade. Its primary decarbonization challenge is now transport, which it primarily wishes to tackle through mode shifting and urban and intercity vehicle electrification, a common strategy across our LAC DDP scenarios.

Ecuador

- While Ecuador has plentiful hydropower today, broad electrification requires diversifying its access to firm clean power sources beyond hydro to supplement future uptake of relatively inexpensive variable renewable sources.
- Developing a bioenergy industry was found to be necessary for deep decarbonisation, specifically for freight and firm clean power.
- An ambitious reforestation program can avoid the dependence on immature, risky and expensive carbon capture and storage (CCS) technologies in the energy sector.
- The Ecuadorian team explored several scenarios with different carbon budgets and the implications of including and excluding AFOLU CO_2 flows. As with all our LAC countries, whether the country includes its typically negative CO_2 land use flows in its carbon budget or allocates them to the global sink has deep policy implications. For the latter to occur, however, international incentive mechanisms are required.

Mexico

- Mexico's current climate change plans and latest energy policy, as highlighted in its NDC (Government of Mexico, 2015), Mid-Century Strategy (SEMARNAT-INECC, Mexico's Climate Change Mid-Century Strategy, 2016), and Energy Transition Strategy (SENER, 2020), aim to reduce emissions intensity per GDP but map out a road towards 2050 which may result in greater absolute emissions than today. The recent focus on long term gas imports from the US, and building of new domestic refining capacity, may lock in unsupportable levels of GHG emissions.
- However, Mexico's very large solar and biomass renewable endowments, industrial base, geographical location, and skilled workforce make a net-zero transformation – which must occur at a global scale – an opportunity to advance towards a high-tech knowledge-based economy, catalyzing economic growth, increased prosperity, less vulnerability to world fossil fuel prices, and greater inclusion.

Peru

- Peru is highly vulnerable to climate change, and its two key contributions are likely to be in minimizing its agriculture, forestry, land use (AFOLU) and personal transport emissions as it develops.
- Peru's current NDC policy actions on AFOLU are pointing in the right direction but need to be considerably strengthened, i.e. 1) Sustainable Management of forest concessions; 2) Improve forest management in native communities; 3) Incentives to native communities for forest conservation; 4) Improve management in Protected Natural Areas; 5) Allocation of rights of use in areas in which they do not exist; 6) Addition of commercial forest plantations.
- There is trade-off between reduced deforestation, afforestation and food production that must be anticipated and planned for.

Introduction

The Paris Agreement's goal of limiting the global temperature rise from pre-industrial levels to 2.0°C and towards 1.5°C requires reaching net-zero emissions of carbon dioxide (CO_2) by 2050-'70, as well as deep reductions in the emissions of other greenhouse gases (GHGs) (Edenhofer *et al.*, 2014; Masson-Delmotte *et al.*, 2018). In this policy report we will focus on the aspirational goal of 1.5°C; the necessary policy actions do not differ as much as the timing of net-zero CO_2 and the scale of the need for net-negative emissions at the global level.

Getting to net-zero emissions of CO_2 is technically possible (Clarke *et al.*, 2014; Fay *et al.*, 2015; Bataille, H. Waisman, *et al.*, 2016a; Bataille, Henri Waisman, *et al.*, 2016b; Davis *et al.*, 2018). Given regional circumstances, net-zero systems transitions in Latin America will have a primary focus on the following strategies: produce zero carbon electricity (e.g. renewable energy combined with firm power support and grid flexibility); undertake widespread electrification (e.g. using electric vehicles, motors, heat pumps and boilers and cooking stoves), and where not possible, switch to other carbon-free fuels (e.g. hydrogen or sustainably-produced biofuels); increase the share of public transportation (e.g. bus or train) and non-motorized transportation (e.g. walking and cycling) in total mobility and reduce demand for transport; preserve and regenerate natural carbon sinks (e.g. by reducing deforestation and promoting reforestation) and restore other carbon-rich ecosystems.

There are large potential benefits associated with a net-zero transition, notably air quality improvements, lower congestion, job creation, and improved and preserved ecosystem services. The transformation to achieve net-zero emissions by 2050 can create immediate and sustained economic opportunities. For instance, OECD (2017) suggests that decisive action taken now towards decarbonization, if accompanied by structural policies, could increase GDP in 2050 by up to 2.8% on average across G20 countries. The International Renewable Energy Agency (IRENA, 2019) argues that a large-scale shift to electricity from renewable energy would boost gross domestic product (GDP) by 2.5% and total employment by 0.2% globally in 2050. Decarbonization does not need to be done at the expense of jobs and growth. By 2030, in a low carbon scenario, structural changes in production and consumption patterns could result in 15 million more jobs in Latin America and the Caribbean compared with a business-as-usual scenario (Saget, Vogt-Schilb and Luu, 2020). The projected gains in employment would largely be the result of changes in diets leading to more employment in the agricultural sector, and to a lesser extent of decarbonizing the energy system.

Delayed or missing action on decarbonization entails high costs. The costs of zero carbon technologies are dropping rapidly whereas business as usual is becoming more expensive and exposed to transition risks including asset stranding; wind and solar backed by short term storage batteries are already the cheapest new generation in many parts of the world (International Renewable Energy Agency, 2020), often lower than the operating cost of coal and gas plants, with costs still falling rapidly at time of writing. At the global level, a pathway immediately aligned with the global goal to reach net-zero emissions by 2050-'70 would require 84% fewer premature retirements of power generation capacity and 56% fewer new capacity additions after 2030 to reach the 2°C target, compared with a pathway based on the current NDCs (Iyer et al., 2015). To meet average carbon budgets from IPCC, 10%–16% of existing fossil-fueled power plants would need to be closed before the end of their technical lifespan (González-Mahecha *et al.*, 2019); building any more fossil-fueled power plants in the region could jeopardize the achievement of the Paris Agreement temperature targets. The IPCC (2018) did not find any pathway that achieves current NDCs and then decarbonizes on time to stay below 1.5°C. In LAC, implementing current NDCs and then correcting course in 2030 to reach carbon neutrality by 2050, would create USD 90 billion worth of stranded assets in the power sector (Binsted *et al.*, 2019). Doing so would also require USD 100 billion more in power plant investments than a transition starting from more ambitious NDC targets in 2020. A rapid and disorderly transition to correct the situation after 2030 would imply grave costs for economies and societies and would likely still not be able to reach the 1.5°C target.

The Paris Agreement operates through iteratively updated NDCs that are to be informed by Long-Term Strategies (LTS). The current round of emissions reduction pledges outlined in the Nationally Determined Contributions (NDCs) submitted around COP21 are insufficiently ambitious to achieve the Paris Agreement goals, partly through absence of goals beyond 2030 (UNEP, 2018). The IPCC (2018) indicates that current NDCs will allow emissions of 52-58 Gt CO_2e in 2030, in contrast to the 25-30Gt CO_2e needed to reach the 1.5°C target. The creation of policies, laws and investments to support the implementation of existing and inadequate short-term targets could erect technical and economic obstacles to achieving the long-term Paris Agreement goals. Inter-American Development Bank (IDB) research shows that, in Latin America and the Caribbean, NDCs fail to put the region on a low emission and economically prudent pathway to achieve the objectives of the Paris Agreement (Binsted et al., 2019).

Country-specific strategies are needed to maximize synergies between deep emission reductions and sustainable development. Deep decarbonisation of energy and land-use systems can complement achievement of national Sustainable Development Goals (SDGs) regarding, e.g., energy security, air quality, equality, and macroeconomic growth (Waisman *et al.*, 2019). But this will be possible only if emission reductions actions are designed with close consideration of each country's goals, challenges, opportunities and national circumstances regarding both climate and development. These global results are true for Latin America and the Caribbean (Inter-American Development Bank (IDB) and DDPLAC, 2019), and the socioeconomic benefits of decarbonization may be even more important in this context given the region's rapidly growing and urbanizing populations. Moreover, the structural social inequalities in this region and the exposure of the most vulnerable population to transition and physical climate risks must be taken into account.

Long term strategies (LTSs) can help guide more ambitious NDCs and policy by establishing a country's vision of specific development outcomes associated with deep decarbonization by mid-century, and identify the sectoral pathways to get there. LTS can also help: inform the re-orientation of infrastructure choices and the design of investment plans to deliver the transition; build policy roadmaps to address regulatory barriers to decarbonization; can help anticipate and manage fiscal impacts; and help governments manage the social impacts of decarbonization to ensure a just and inclusive transition. Not insignificantly, the process of building an LTS can help both solicit critical information from stakeholders as well as build their knowledge base and comfort level with the physical transitions and policies needed.

Several key principles have emerged in recent years to guide the elaboration of long-term strategies (Waisman *et al.*, 2019):

- begin with the net-zero end in mind; from that desirable future work backwards (a.k.a. "back-cast") to identify policies and programs that will connect that specified future to present actions.
- canvass stakeholders, especially those critically affected or who must implement the transition, as well as experts for potential national and sectoral strategies to reach the net-zero goal;
- quantify, compare and contrast these strategies in an integrated way to build common pathways, while using the process to build stakeholder knowledge and consensus;
- and finally, build adaptive policy packages with clear roles and timeframes for stakeholders to achieve the pathways.

These principles guided the design of the Deep Decarbonization Pathways in Latin America and the Caribbean (DDPLAC) project[1] led by the IDB, in partnership with the 2050 Pathways Platform and the Agence Française de Développement (AFD), and drawing on the experience of the Institute for Sustainable Development and International Relations (IDDRI.org). Under this project, domestic universities and think tanks from six LAC countries (Argentina, Colombia, Costa Rica, Ecuador, Mexico, and Peru) investigated national decarbonization pathways. The teams used models describing the energy, agriculture and land-use systems, built a partnership with international experts, created a regional peer-to-peer exchange platform, and discussed decarbonization scenarios with policymakers, civil society, and other stakeholders in their countries.

1 More details about this project can be found in IDB's "Getting To Net-Zero Emissions: Lessons from Latin America and the Caribbean"(Inter-American Development Bank (IDB) and DDPLAC, 2019) as well as a special issue of Energy Strategy Reviews, with a group synthesis paper (Bataille et al., 2020) and associated country papers.

How to revise NDCs to make them consistent with long-term goals

While it is widely acknowledged that current NDCs are not ambitious enough to achieve the objectives of the Paris Agreement and lead to a global warming of around 3°C by the end of the century (Hausfather and Peters, 2020), these high level assessments do not directly inform how to concretely revise individual country NDCs to make them more aligned with the global climate target.

The analysis conducted in the DDPLAC project, where country teams simulated NDC and deep decarbonization pathways using models developed for the purpose, provides such a guide. In **Figure 1** the DDP scenarios describe emissions trajectories consistent with the global climate goal to 2050, and the milestone points in 2030 therefore constitute benchmarks against which the NDCs can be assessed. **Emissions per person in the DDP runs are typically 25-33% less in 2030 compared to the NDC runs;** Costa Rica's original NDC was compliant with 2°C, and they have since revised their ambition to 1.5°C.

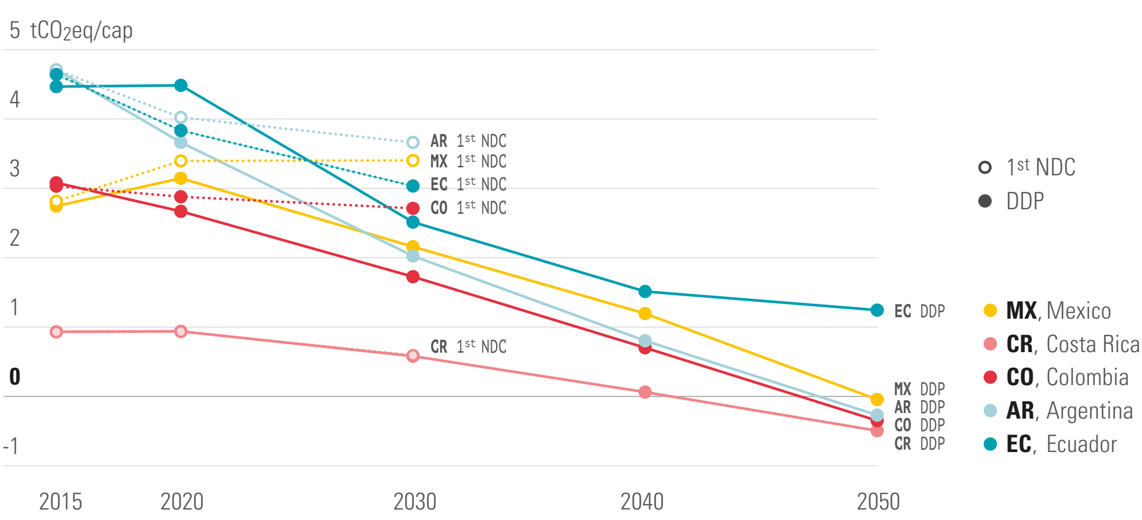
Moreover, the DDP analysis allows the policy conversation to go one step further, by providing a reference for evaluating the scale of the key sectoral transformations that need to happen if the world is to follow a Paris compatible pathway. This information provides a concrete guide for revising the NDCs by indicating where the country effort should be increased; this will be key to facilitating implementation of NDCs.

More specifically, in addition to their sectorally detailed DDP scenarios, most of the country teams have developed a current NDC scenario which provides a sectorally detailed picture of the transformations implied by the current NDC goals. The comparison of this with the detailed DDP scenario can therefore help governments prioritize where sectoral expertise should be sought in order to revise their NDC ambition towards long term compliance with the Paris goals, and policies to achieve this ambition.

To each physical indicator characterizing the transformation, we associate a measure of the "percentage of 2015-2050 effort" calculated as the ratio between the variation of this indicator between 2015 and 2030 and the 2015-2050 variation in the DDP scenario. This comparison of this ratio between the NDC scenario and the DDP scenario helps identify the main dimensions where ambition is insufficient. We present here some illustrations of these comparisons for key indicators in energy, transport and land use.

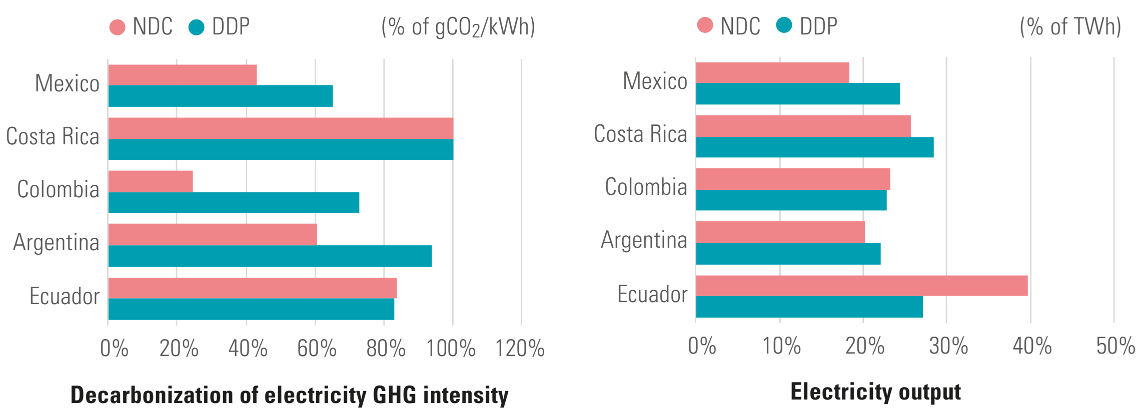
For energy, we focus on electricity production, because electrification is in all cases a key pillar of de-

Figure 1. Projected combustion (not including process) and AFOLU NDC and DDP CO2 emissions, excluding other GHGs



carbonisation. We distinguish two sub-components: the carbon content and the volume of production (**Figure 2**). The former is supposed to decrease dramatically and the latter to increase substantially in Paris-compatible scenarios. In three countries, Colombia, Mexico and Argentina, it appears that the rate of generation GHG intensity decarbonization implied by the NDC is largely insufficient, implying the creation of stranded assets. In two other countries, Ecuador and Costa Rica, however, the decarbonization of electricity in NDC is well aligned with requirements for DD. In Costa Rica, electricity production is already completely decarbonized (starting from an already very low-carbon basis). In Ecuador the electricity system is also very decarbonized in the NDC, due to recent expansions in its hydropower fleet; it should also be noted from the demand figure, however, that electrification plays a less important role for decarbonization than in other countries. The figure on electricity production shows that, as a first order estimate, demand/power generation projections in the NDC correspond well to the scale to envisaged in DDP, with Mexico as an exception. In sum, the projected amount of power available in 2030 is not an immediate issue - its GHG intensity of production is, however. On this Argentina, Colombia and Mexico vary between only 40 to 60% of the necessary GHG intensity decarbonization by 2030 in their NDCs. Put simply, these countries do not plan to decarbonize their electricity supply fast enough – confirming at country scale the results by Binsted *et al.*, (2019).

Figure 2. Percentage of DDP 2050 electricity decarbonization done in 2030 in the NDC and DDP scenarios



Notes: Figure 2 provides a relative measure of 1) GHG intensity decarbonization and 2) output growth in the NDC and DDP scenarios by dividing, for each indicator, the 2020 through 2030 change in the DDP and NDC scenario, respectively, by the 2020 through 2050 change in the DDP scenario.

Figure 3. Percentage of DDP 2050 transport done in 2030 in the NDC and DDP scenarios

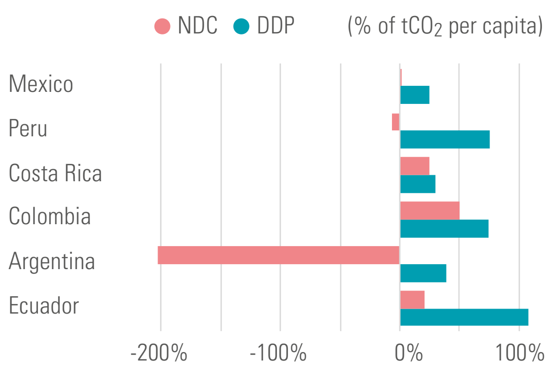
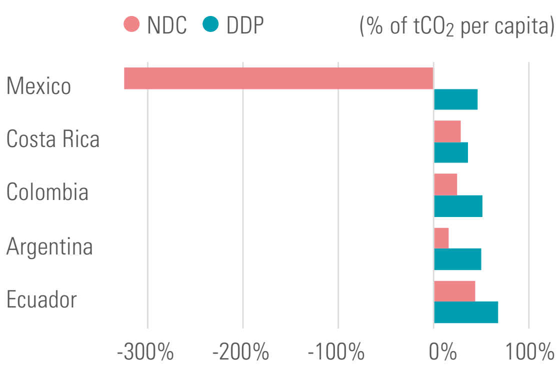


Figure 4. Percentage of DDP 2050 AFOLU decarbonization done in 2030 in the NDC and DDP scenarios



Passenger transport is a big topic for NDC enhancement (**Figure 3**). In almost all countries, except Costa Rica and Colombia to some extent, the rate of effort is largely insufficient or even goes backwards in the NDC in the case of Argentina and Peru. The delay in action in NDC reflects a combination of insufficient measures for incentivizing the diffusion of low-carbon vehicles, notably for road transport, for enabling a modal shift towards low-carbon modes, and to control mobility demand. These actions entail potentially important inertias linked to land use planning and infrastructure deployment; the delay in the NDC results imply high potential emissions lock-ins.

Finally, the Agriculture, Forestry and Land Use (AFOLU, 1/3 of total GHGs) sector is probably the most difficult challenge from a political economy perspective because the issue is not technology but incentives for land use. in that the analysis shows that action is significantly not ambitious enough compared to what would be required (**Figure 4**), and in some cases even directionality is completely absent. Mexico is particularly a problematic case, as AFOLU emissions are rising in the NDC. Unfortunately, Peru, our most advanced AFOLU study, did not have an NDC scenario for comparison. Given path dependencies in this sector, the NDCs create a risk for the long-term natural carbon sink capacity. Given the importance of the LAC region for global land use sink capacity, the enhancement of the AFOLU component of NDCs is a key area for policy application, and given the potential costs of afforestation, global cooperation.

How Long-Term Strategies can help with real-world policy formation

How the LTS development process can enhance buy-in by stakeholders

Notionally, all our LAC countries, in committing to the Paris Agreement, have committed to the goal of global net-zero emissions by 2050-'70 to meet the 1.5-2°C temperature targets, broadly implying national, sub-national and sectoral climate targets and development goals need to be adjusted to include net-zero GHG emissions later this century. But what does this mean for each LAC country and region, and individual economic sectors within these countries? How can LAC countries build the political consensus to trigger the economy-wide net-zero transition and ensure a just and inclusive transition? And what potential mixes of policies can help implement this transition in a way that will be effective, efficient and enjoy sufficient acceptance from all stakeholders that must implement the transition or will be affected by it (e.g. government departments, firms, communities, labour, and other NGO stakeholders)? The capacity of national low-emission development strategies to address these questions will largely depend on the organization of the stakeholder engagement processes to develop them, and the analytical processes used to test the rigour of physical transition and policy propositions from these processes. Some of our LAC teams, especially Costa Rica and Ecuador, have done some of this stakeholder consultation already. Moving forward, specific attention should be given to framing the need for net-zero in the context of other development goals, the ability to apply quantitative rigour to the transition narratives offered by stakeholders, and any specific institutional arrangements needed to enhance stakeholder involvement.

The LTS process "framing" or "scoping" statement should ensure clarity on the objective of the analysis by all stakeholders, i.e. consistency with global CO_2 emissions neutrality in the early latter half of the century. To help keep the net-zero goal in mind, back-casting from a 2050-'70 vision to the present at the sectoral and summed national level helps identify the public policy, planning and investment choices needed to achieve this vision, particularly for long-lived infrastructure, as well as an appropriate sequence of policy actions for a just and inclusive transition. Shared understanding and ownership of this frame is a key condition to ensure buy-in of the challenges and opportunities to be investigated, and active participation in looking for solutions. The scope of the LTS development process should illuminate the challenges and opportunities of long-term low-emissions development in the context of the country. This implies engaging stakeholder concerns as a means to canvass their knowledge and opinions on options, build working consensus, and through testing across many perspectives ensure the robustness of the approach. At the same time, the long-term horizon of the pathways analysis should be forthrightly employed to avoid a focus on narrow or short-term interests (e.g. those who wish to build gas infrastructure must demonstrate how it is consistent with net-zero GHG emissions past 2050-'70). Finally, recognizing the pressing priority of existing development goals (e.g. poverty alleviation, reduction of inequality and unemployment, air quality improvement, and improved power access and reliability), long term transformation options will have to be evaluated in the light of their ability to contribute to synergistically meeting development and climate change goals at the same time. Taking this argument further, development policy that pays for itself while having climate benefits (e.g. electrification of public buses with more frequent and broader service to meet urban air quality goals) will take precedence.

Quantitative analytical approaches and modeling tools should be selected for their ability to use, reflect and produce pathways inputs, assumptions, and results in a way that rigorously and transparently answers the questions of "who does what, when, and who is impacted?" at the appropriate temporal, geographic, and sectoral resolution. The process of matching research and policy questions to analytical tools can help to identify resource and capacity challenges, such as whether current tools are adequate or new tools are needed, or what skills or forms of technical assistance may be needed to perform the analysis. Understanding what data are readily available, what could be made available, and what is not available at all will determines what analysis can be done in a robust manner, what requires simplified treatment, and what should be excluded from the analysis. For governments that lack their own data in key policy areas or sectors, international, sectoral, and proxy datasets from governments with similar conditions can be used in an initial phase.

Specific institutional arrangements are required to structure the involvement of stakeholders in pathways studies. Stakeholders can include other government departments or local governments, public and private companies, non-governmental organizations, think-tanks, institutional investors communities, or trade unions. Co-construction and consultation with stakeholders can help countries build LTSs that are relevant, support multiple development objectives, and have buy-in from stakeholders. Qualitative and quantitative narratives, offered by stakeholders in their own language but translated into common quantitative dashboards, are a key strategy for engaging them in pathways design. The objective should be to organize a two-way communication between the quantitative analysis and the stakeholders to solicit their input and feedback, and report progress and results, at different stages of the process and in particular in the early stages. These iterations are essential to generate robust scientific and technical knowledge reflecting real-world situations, to facilitate assimilation of these scientific insights by decisionmakers, to identify synergies and trade-offs and find ways to manage them, and to help identify areas that are ripe for innovation and transformation and the means to induce.

Once working agreement on one or more net-zero pathways have been established, and the physical transitions (and their potential variations) each sector must embark upon in the short and long run have become clear, then the task of building suitable short and long policy packages must be addressed. Realistically, this will require government initiative and active and constructive stakeholder feedback, making initial buy-in all the more important. Not all policy options will be suitable or available in all countries, and each country's government will have to tailor those that make sense for their transition to their governing system, stakeholders, capabilities, and national circumstances. Explicit or implicit carbon pricing in particular requires a point of incidence, where the charge can be applied or the subsidy reorientated to carbon intensity. In informal economies with absent excise tax structures, the only available point of incidence may be where the final energy form is produced or imported. The same applies for regulations; if building codes either do not exist or are not enforced, energy efficiency and electrification needs to be actualized directly through construction firms and suppliers of construction inputs.

Economy wide and sectoral policies

There is a well-established suite of policy tools from which to build policy packages, including: stakeholder consultation, planning and consensus building (see above sections); removal of regulatory barriers (e.g. buildings codes) to decarbonization processes (e.g. more efficient steel and cement use in buildings; substitution of clinker in cement); regulatory measures, including technology and performance standards; market measures, include direct subsidies, fossil fuel subsidy reduction & carbon pricing; and innovation policy, including support for research, development and commercialization, including early market support. These generic policy tools are typically evaluated against the following criteria in a given context when forming policy packages: effectiveness in achieving the goal; economic efficiency (lowest cost per tonne avoided); distributional effects/equity; transformational potential (i.e. to induce technological or structure innovation); socioeconomic benefits (especially local air pollution and paid employment) and general alignment with broader development goals; interactive effects with each other and other policies in effect; and administrative and political feasibility. The last criteria is perhaps the most challenging, as it includes real world considerations of winning political acceptance, the behaviour and decision making of those who must implement the physical transition actions, managing competing objectives, and the importance of local context in the effective design and implementation of climate policy. Finally, the transition towards net-zero emissions will likely create winners and losers, with negative social impacts if not carefully addressed and planned for. Given all the above we suggest the following key economy wide and sectoral policy package elements, to be administered as appropriate in given sectors, regions and countries.

We will first discuss a set of economy wide policies, then sector specific policies as emerging from the DDP analysis. Each section includes a discussion of any key enabling conditions, capacity building & needs for international cooperation.

2 https://www.npr.org/2019/10/14/770104729/ecuador-reaches-fuel-subsidy-deal-to-end-violent-protests; https://www.petroleum-economist.com/articles/politics-economics/south-central-america/2019/ecuador-reverses-fuel-subsidy-decision

Economy wide: Reduce fossil fuel subsidies, reorientate existing fuel taxation towards GHG intensity, and make finance available for strategic investments while planning government revenues and costs

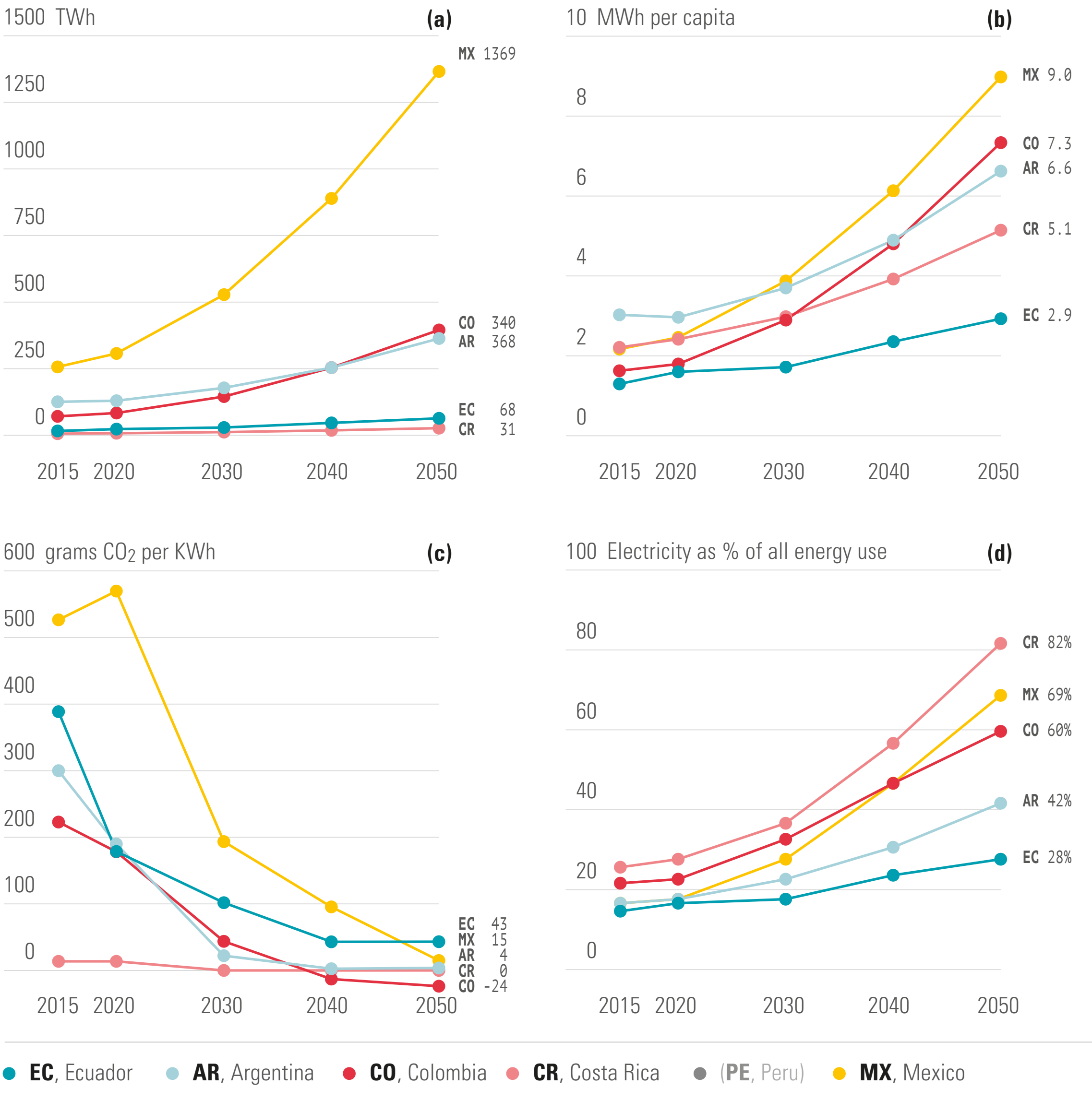
The IEA indicates annual narrowly counted ("price-gap") fossil fuel subsidies at $400 billion USD in 2018 (https://www.iea.org/topics/energy-subsidies). While the removal of fossil fuel subsidies can be very difficult, as Ecuador's recent unsuccessful attempt to reduce diesel, gasoline and LPG subsidies leading civil unrest has shown[2], this will likely be very important for the long run transition to net-zero emission in transport, buildings and industry. Policy makers need to watch for and seize windows of opportunity, like periods of low energy costs, to reduce consumption and production subsidies. Complementary measures are also required to shield the poor and most vulnerable in the transition, for example direct cash transfers to the most vulnerable in response to removal of subsidies or energy or carbon pricing (Vogt-Schilb *et al.*, 2019). Extending the logic of reducing subsidies, reorientation of existing fuel excise taxation towards GHG intensity, as carried out by the Scandinavian countries in the 1990s as part of a broader tax reform, can mimic the effects of a low but effective carbon price. Sweden in particular implemented their carbon tax, currently at $123/t CO_2e the highest in the world, as part of a major tax reform in 1991, where they introduced carbon pricing as part of a larger reform to reduce high marginal income taxes in exchange for broader value added taxes. "Tax swapping" can also introduce the public to carbon pricing in a relatively neutral way, allowing further increases later; the High Commission on Carbon Prices recommended $40-80/t CO_2e by 2030 and $50-100/t CO_2e by 2050 (Carbon Pricing Leadership Coalition, 2017). Carbon pricing, while useful for incenting long term structural changes and innovation in the economy, can be very difficult politically, and even if successful it may be necessary to implement a lower than optimal schedule of prices. Despite economic orthodoxy, policymakers should also not be afraid to impose different prices across sectors, regions and nations – the welfare response to carbon pricing can and will differ (Bataille *et al.*, 2018), and the efficiency of price signals to trigger changes will differ across sectors. California implemented a suite of regulatory policies to deliver most of their emissions mitigation goals and implemented its cap and trade system as a backstop insurance policy (Bang, Victor and Andresen, 2017).

Deep decarbonization will also affect sectors that contribute towards a country's fiscal revenues, starting with LAC countries currently receiving oil and gas revenues (Solano-Rodriguez *et al.*, 2019). When reducing subsidies for fossil fuels, providing subsidises for low GHG power generation and EVs, and otherwise employing fiscal adjustments that behave like carbon pricing, careful assessment needs to be made of anticipated net government revenues and costs.

Economy-wide: All sectors must be encouraged to electrify, use local renewables, or otherwise use decarbonized energy where possible

With the caveat that electricity generation must evolve to complete decarbonization, technology or performance standards will be needed to encourage and possibly mandate electrification of energy end-uses, i.e.: cooking; heating; space heating; small and large steam and heat sources (e.g. boilers and heat pumps for commercial and light industrial end-uses); and personal and public transport. To support this electricity generation will need to be decarbonized (next section), transmis-

Figure 5. Total DDP electricity generation in TWh (a), MWh per capita (2015=1) (b), GHG intensity in grams CO2/kWh (c), as % of all final energy use (d)



Source: (Bataille et al., 2020)

sion will need to be improved, and key technologies will need to be available, e.g. induction plates and cooking materials; residential, commercial and industrial heat pumps; solar hot waters and electric boost systems; and electric personal vehicles, buses, and trucks. To meet these needs electricity production per capita rises 4-5 times per capita from today by 2050 in all the DDPLAC analyses, and electricity generation GHG intensity falls to virtually nil (**Figure 5**). Light industry will need education and financial encouragement (e.g. through tax mechanisms) to use direct solar heating, heat pumps, and electric resistance boost heating in place of coal, LPG or NG boilers. Policies will be needed to encourage uptake of best practise industrial direct or indirect (i.e. via hydrogen from electrolysis) electrification when established (e.g. in steel making or nitrogen fertilizer making). Finally, assessment will need to be made of whether a region's electricity and fuel price signals are aligned with deep decarbonization; do they work for or against implicit carbon pricing?

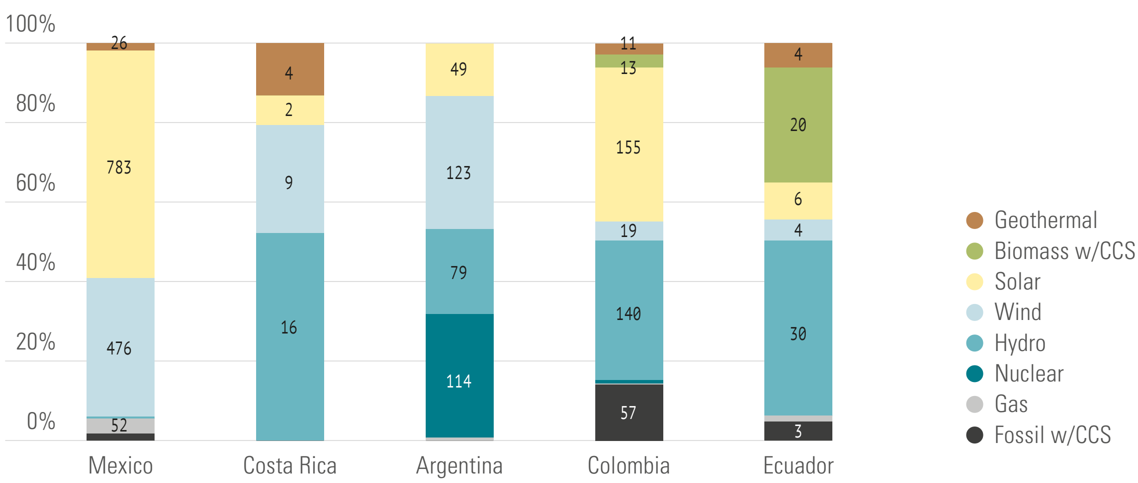
LAC national and regional governments already have most of the governance tools they need to encourage electrification and fuel switching to net-zero carbon fuels (e.g. bio or hydrogen rich synthetic liquids and gases) once they become available. Bio and synthetic fuels will be globally developed technologies, with likely key contributions from Brazil and other LAC countries, and it will be key that LAC countries actively participate in developing the demand side of the market, along with all other jurisdictions.

Sectoral: Energy – All new electricity must be very low or zero emission, and high GHG assets phased out

To support economy wide clean electrification, all new electricity generation must be very low (e.g. -95% CCS or better) or zero GHG emitting, or be for purpose of supporting (i.e. providing "firm" power) uptake of more variable renewables (i.e. solar and wind). This can be imposed through renewable portfolio standards combined with market auctions with maximum GHG intensity standards. Unless mandated otherwise, most new zero GHG generation will come from wind and solar on a cost per kWh basis, which will require intermittency planning and support along the minute, hourly, weekly and seasonal dimensions. Blocks of wind and solar can also be sold into the market combined with integration support. This support can be provided using more planning, regional interties, demand response, energy storage (e.g. batteries, fossil fuels with CCS, gas turbines that can run on a mix of gases or liquids (i.e. methane, propane, LPG, hydrogen), or two-way fuel cells implementing power to hydrogen and back, etc. Finally, the national and regional governance and market structure for electricity and natural gas must be reviewed for dynamics that will work for and against electrification, e.g. legacy reserve margin rules based on probabilistic large coal plant outages.

Countries such as Chile and Mexico have run very successful auctions for renewable power, with recent unsubsidized prices of \$0.029/kWh USD and \$0.021/

Figure 6. DDP electricity generation mix by country in 2050 (TWh)



Source: (Bataille et al., 2020)

kWh respectively and individual projects between \$0.017/kWh and \$0.032/kWh. All these prices are below the cost of coal or gas generation, and inter-regional cooperation can help repeat these successes.

Countries and regions are likely to need planning, market design, and finance for growing and refurbishing their power generation and transmission systems. While most of the finance will need to come from the private market, "derisking" signalling finance from development banks can help attract attention to these projects from the market. Ultimately, however, domestic and international public funds represent a tiny fraction of the investment needed to decarbonize (Fay *et al.*, 2015), and the key for governments is to redirect both public and private investments. A catalytic role for international financial institutions can be to help reshape private and domestic government expectations, financial regulations and institutions towards that goal.

Sectoral: Energy - Carefully reconsider investment in new coal, oil and gas projects for export and domestic use, including exploration, production and transmission

For existing national production of coal, oil and gas, the LAC countries should develop an asset optimization strategy based on GHG intensity (i.e. ramp down coal, oil and gas assets in that order as possible, with consideration for specific investment amortization lives), taking into account how they can be adapted to low carbon energy production. If planned for, some oil and gas infrastructure and facilities can be used to make low GHG hydrogen, bio-liquids and -gases, and other low carbon fuels (Bataille 2019). Public funds for suspended oil and gas works can be redirected into electricity transmission, distribution, and energy storage infrastructure to enable high volumes of renewable generation to be included into the grid.

The early 2019 OPEC price war and the COVID-19 driven fall in demand for fossil fuels has exposed the price uncertainty in global oil and therefore gas markets, and in this light new oil and gas exploration for export should be considered highly risky. Coal, oil and gas exploration that is intended to be tied to use of domestic carbon capture and storage may be less risky under the condition carbon capture and storage is commercialized globally at a reasonable installation and operation price.

Sectoral: Transport - Use land use & transit planning and zoning to encourage non-motorized, high occupancy low emissions travel.

Decarbonizing the transport sector while increasing access to clean and safe transportation options brings opportunities to improve mobility, reduce local air pollution, and improve the quality of life. Many cities in LAC are above the World Health Organization thresholds for the concentration of airborne pollutants. Every year, 50,000 people die prematurely in the region due to air pollution caused mainly by transport (Galarza and López, 2016).

Urban and transit planning is needed to gradually restructure LAC cities towards an urban form that encourages more high frequency transit (e.g. electric buses and trains) and non-motorized mobility. This includes short term efforts, e.g. movement regulations to encourage either non-motorized modes or transit (e.g. raised and separated sidewalks, bike lanes with barriers, removal of parking, land use regulations to concentrate symbiotic businesses and services), and longer term efforts, where city growth and evolution is directed towards encouraging high occupancy low emissions transit and away from car traffic. **Figure 7** shows how total mobility increases in all but Ecuador and motorized individual mobility falls in all but Argentina, mainly due to mode shifting to electrified urban and intercity bus lines.

Sectoral: Transport - Mandate zero emissions for new vehicles, and create the enabling conditions/incentives for innovative transport business models

Battery electric, and hydrogen fuel cell vehicles to a lesser extent, have entered the commercial global transport market, and promise a pathway to eventually eliminate direct GHG and local air pollutants in global cities, if not congestion. Electrification of vkm varies from 6% to 100% by 2050 in our DDPLAC scenarios, with the majority in the 40-65% range (**Figure 8**); while fuel GHG intensity, which includes switching to biofuels, varies from -18% to -100% by 2050 (**Figure 9**). Net-zero emissions vehicles currently cost more than gasoline and diesel-powered equivalents, however, and the availability of recharging and refueling networks can vary from non-existent through limited, while growing quickly in some regions.

According to the IEA Global EV Outlook (Till *et al.*, 2019) policy approaches to promote the deployment of EVs typically start with a vision statement and a set of targets, followed by the adoption of electric vehicle safety and interoperable network charging standards. An EV deployment plan often includes public procurement programmes to stimulate demand for electric vehicles and to enable an initial roll-out of publicly accessible charging infrastructure. Policies to support deployment of charging infrastructure include minimum requirements to ensure EV readiness in new or refurbished buildings and parking lots, and the building of publicly accessible chargers in cities and on highway networks. Measures that provide crucial incentives to scale up the availability of vehicles with low and zero tailpipe emissions include fleet fuel economy standards that tighten to zero emissions through time. Another useful policy measure is to provide economic incentives, particularly

Figure 7. 7 DDP motorized distance travelled per capita (pkm/cap) (a) and motorized individual mobility (Car + two-wheel vehicle) share (% Gpkm) (b)

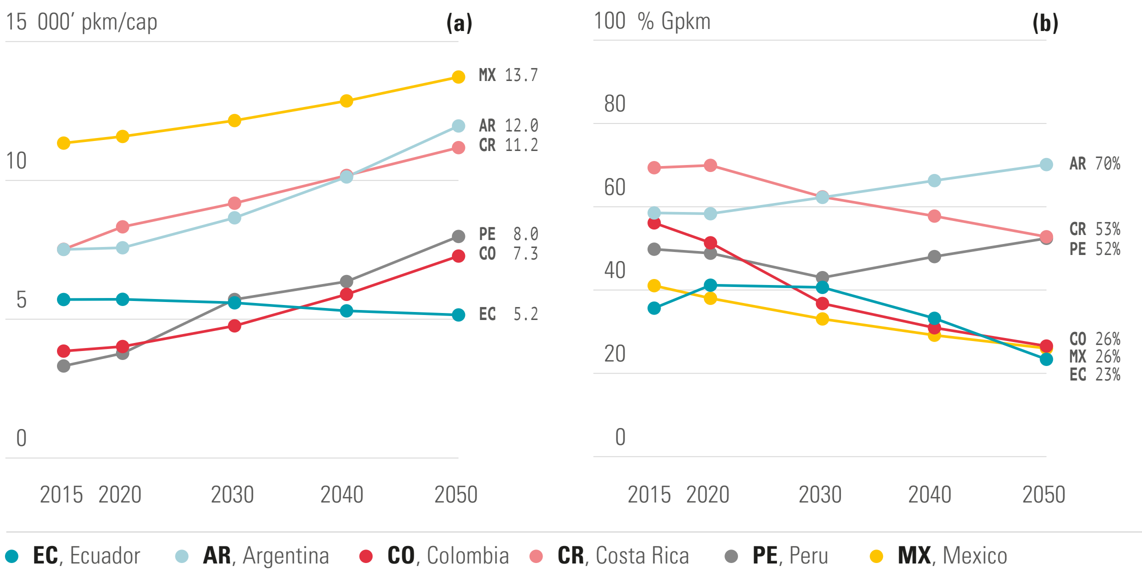
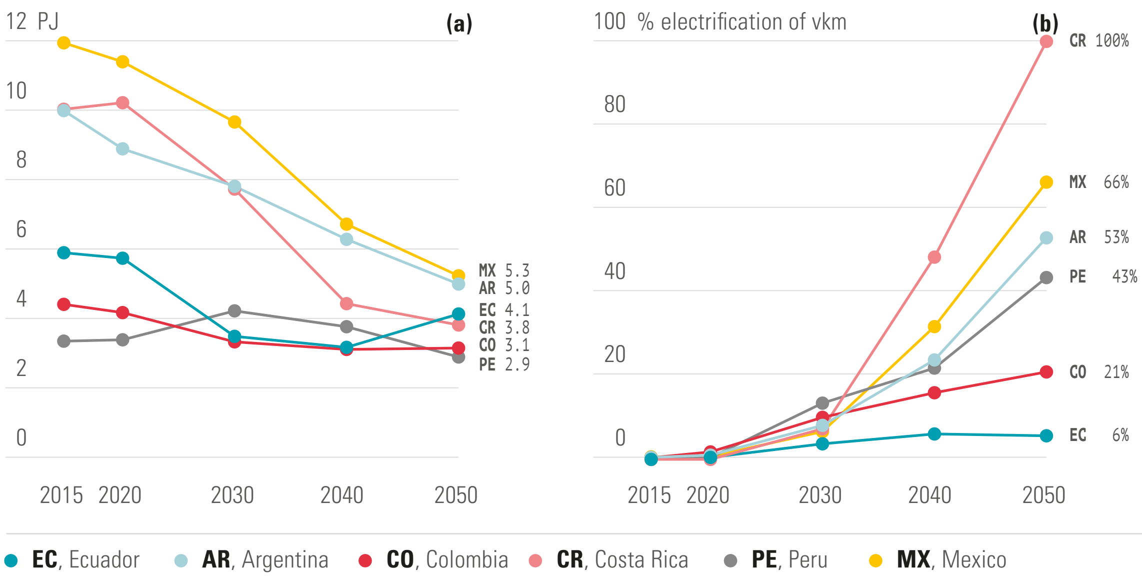
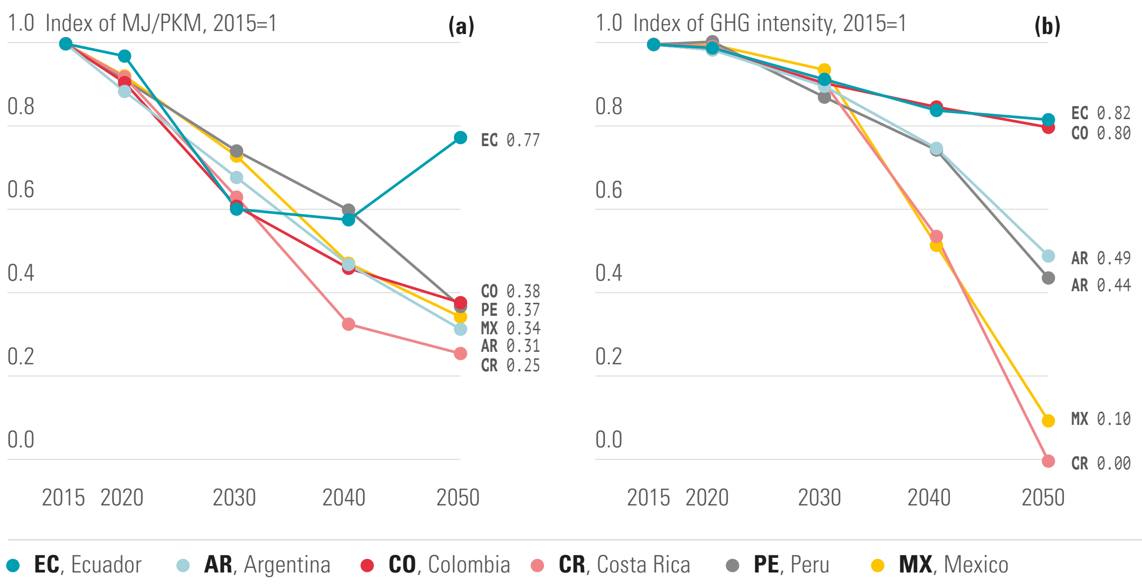


Figure 8. Total energy consumption for passenger transport (PJ) (a) and electrification of all vkm (%) over time (MJ/pkm, 2015=1) (b)



Source: (Bataille et al., 2020)

Figure 9. Passenger transport energy efficiency (a) and overall fuel end use GHG intensity (b)



Source: (Bataille et al., 2020)

to bridge the cost gap between EVs and less expensive internal combustion engine (ICE) vehicles as well as to spur the early deployment of charging infrastructure. These are often coupled with other policy measures that increase the value proposition of EVs (such as waivers to access restrictions, lower toll or parking fees) which are often based on the better performance of EVs in terms of local air pollution.

In the Latin American context, working with the strategy of encouraging high occupancy low emissions urban and intercity travel, business models that help encourage electrification of bus systems (e.g. lease back systems given their high upfront costs) could be transformative. Car, bus and urban freight motorized travel can also be required to transition to zero GHG and local air pollution motors (e.g. electrification and hydrogen fuel cells) via implementation of fleet standards and "clunker" retirement schemes. All heavier and longer-range freight must eventually decarbonize as well, with a mix of electrification, biofuels or hydrogen fuel cells likely depending on the mode, size, route of vehicles and global technological developments.

Again, LAC national and regional governments have most of the governance tools they need for urban planning and vehicle regulations; Ecuador has already mandated all new city and inter-city buses be electric by 2025, and Costa Rica is targeting electrification of the public (30% by 2035 & 85% by 2050) and private (95% to 2050) bus fleets. Where they may require aid and encouragement is implementation of best practises in urban planning, and signalling finance for capital intense urban transit projects to help encourage the participation of the needed private finance.

Sectoral: Agriculture, Forestry and Land Use - Engage sustainable intensive agriculture to reduce N_2O and methane emissions through better farmer practices, and to reduce deforestation pressures

Several of the DDPLAC partner teams (Peru, Colombia, Ecuador, and Argentina) identified sustainable intensification (e.g. more output per hectare) of agriculture and livestock raising as a means to reduce N_2O and methane emissions, including more efficient use of fertilizers and irrigation, dry periods for rice fields, crop and fallow selection to increase soil carbon, etc.

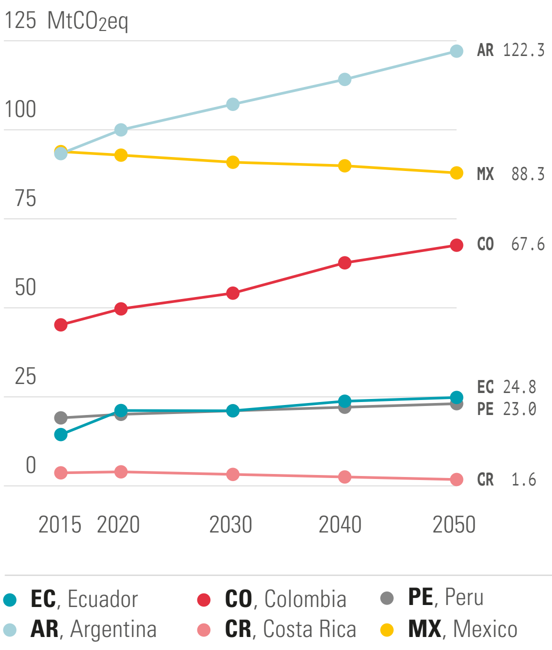
Because nitrous oxide and methane fertilizer and land use emissions outcomes very much depend on the methods farmers use, and will always be difficult to count, these emissions must be reduced through land use regulation, farmer education, and finance mechanisms for the farming community, e.g. fertilizer pricing. Education for farming also often involves a move from subsistence, low productivity agriculture to more professionalized farming. This is within the means of LAC countries but will require a 10-20 year investment in education, and measures to allow currently subsistence farming families to engage with this system.

Nitrous oxide and methane from ruminants (cattle) are proportional to the number of cattle, which is related to human diets, but also the cows' diet. Research is ongoing into vaccines and diet changes to reduce ruminant methane, e.g. by feeding them a small portion of a specific species of seaweed.

While almost all the DDPLAC teams showed flat or increasing agricultural CH_4 and N_2O emissions (**Figure 10**), several noted in their reports that more intensive sustainable agricultural practises could also help reduce pressure to add more farmland through deforestation, and help release previously degraded lands for afforestation.

During the DDPLAC project the teams didn't include large changes in diets, while the subsequent IDB report on jobs (Saget, Vogt-Schilb and Luu, 2020) is premised on a large scale change in agriculture from meat and dairy products to more vegetal production based on diet changes. This has large potential downstream health benefits, and large potential upstream employment and GHG emissions benefits from reduce cattle methane and N_2O (Masson-Delmotte *et al.*, 2018).

Figure 10. Agricultural emissions, CH4 and N2O (MtCO2e)



Source: (Bataille et al., 2020)

Sectoral: Agriculture, Forestry and Land Use - Engage assignment and enforcement of land use rights to allow reduced deforestation, supplemented with commercial afforestation

Several DDPLAC teams suggested that that assignment and enforcement of land ownership and use rights (especially for subsistence farmers and indigenous peoples) would help reduce deforestation CO_2 flows and help release agriculturally poor lands for afforestation (**Figure 11**). Creating this enforceable, long term association between communities, agricultural lands, and standing and growing forests produces an incentive to protect and enhance them, as well as longer-term investments in sustainable agroforestry, where forests are "farmed" for high value food, animal, pharmaceutical and other products but left to stand, grow and absorb carbon. This was addressed at some length in the Peruvian DDP work and resulting papers.

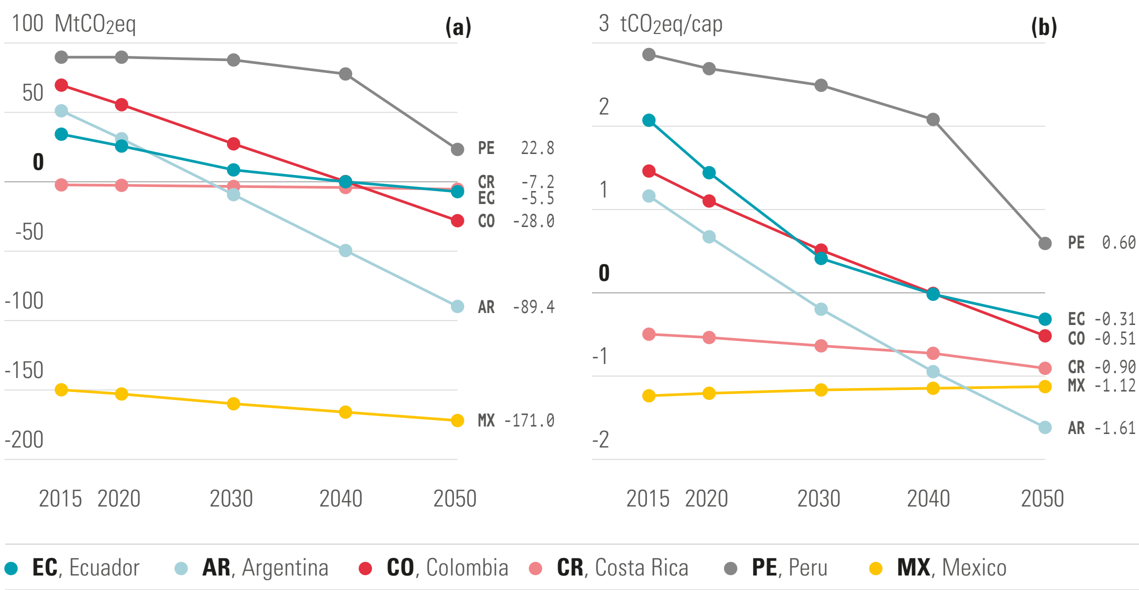
Additionally, large afforestation programs could both protect existing exposed forests and absorb carbon dioxide in their own right. The Peruvian team included a specific suggestion for an afforestation program to buffer existing Amazonian lands that would sequester between 1-2 GtC for $2 billion, effectively $1-2/t CO_2. The funds for such a project would have to come from outside the Peruvian government, however.

Land use rights assignment and enforcement are domestic prerogatives, but are one of many development priorities for LAC national and regional governments, and they may not be the highest. Also, as Colombia's experience with the end of their civil insurrection, where the end of violence allowed deforestation to resume in FARC areas, subsistence slash and burn agriculture and illegal land seizure and forestry are hard to avoid if local populations do not have other options. There may be room for funding and logistical support for land use rights enforcement, education for wages labour and sustainable agroforestry, access to higher value-added markets for forest protein and vegetal products, and especially for commercial afforestation programs, all respecting local government priorities. Please refer to "Jobs in a Net-Zero Emissions Future in Latin America and the Caribbean" (Saget, Vogt-Schilb and Luu, 2020).

Sectoral: Participation in structured and intensive innovation and commercialization programs and market pull mechanisms to deal with "hard to abate" sectors, e.g. aviation, freight, and heavy industry.

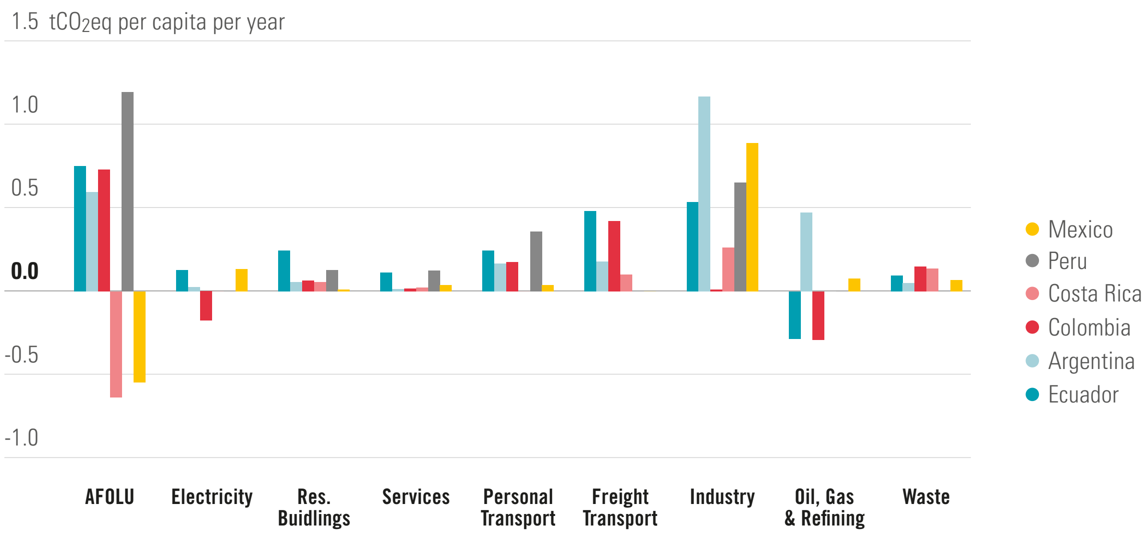
The LAC countries all have substantial aviation, freight, and heavy industry emissions (**Figure 12**), all of which must go to net-zero emissions as well. While the LAC nations have a substantial challenge transforming their electricity, transport and industrial systems, as best available technology improves in the aviation, freight and heavy industry sectors they should also monitor and adopt these improvements, and contribute to global efforts as they are able.

Figure 11. Land use change emissions by country: absolute (Mt CO_2) (a) & per capita (tonnes CO_2 per person) (b)



Source: (Bataille et al., 2020)

Figure 12. Remaining 2050 emissions by sector per capita (tonne CO_2e per capita per year)



Source: (Bataille et al., 2020)

It is not out of the realm of possibility that Mexico's solar resource, Argentina and Chile's wind and solar, and the entire region's plentiful biomass, may be key to producing net-zero materials (e.g. zero emissions iron from Chile using hydrogen reduction) (Armijo and Philibert, 2019), fuels and keystone chemicals (hydrogen, ammonia, ethylene, methanol) (Armijo and Philibert, 2019; Bataille, 2019).

The DDPLAC project has shown that achieving net-zero emission by later this century is technically achievable using known physical and policy pathways mostly well within the capabilities of these countries, and that there are substantial potential macroeconomic, air quality and energy security benefits. Achieving these pathways will require the active participation and cooperation of all stakeholders in the formation of long-term development strategies, strategies which, once established and agreed on, will allow the choice and implementation of economy wide and sectoral policy packages suited to each country and sector to drive the physical transformations. Long-term strategies can also help governments manage the social impacts of decarbonization and ensure a just and inclusive transition (Saget et al 2020). Some key international enabling conditions may be helpful, in the form of key technological advances & commericialization, de-risking "signalling" finance for energy and transit infrastructure, and direct international funding and logistical support for domestically controlled land use rights assignment and enforcement, forest community general and specifically agroforestry education, and very pointedly for direct afforestation programs to protect and enhance existing forests.

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COUNTRY PERSPECTIVES

ARGENTINA

COLOMBIA

COSTA RICA

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ARGENTINA
GETTING TO NEAR NET-ZERO EMISSIONS

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Key policy messages

- Argentina's NDC measures are consistent in direction but not in depth with deep decarbonization.
- Electrification of most final energy demand is necessary for decarbonization.
- Growth of variable renewable energy to 50% of generation by 2050 is necessary across our scenarios.
- The development of a hydro-nuclear program that complements renewable energy development emerges as the favoured option for reaching decarbonization objectives, with the best impact in terms of activity, employment and productive dynamics.
- The availability of a mature and competitive CCS and/or blue hydrogen produced from natural gas technologies are required if *Vaca Muerta* – a major non-conventional hydrocarbons formation - is to play a large and positive role in the Argentinian scenarios, by using its natural gas for electricity generation and eventually for export.
- Paris Agreement compliant per capita emissions goals will be difficult to achieve without afforestation as a core mitigation strategy to offset emissions from agricultural-livestock productive activity.
- The large investment needs required to reach Argentina's Deep Decarbonization objectives will require more substantial, efficient, and cooperative financial resources.
- If decarbonization of Argentina is to be reached jointly with needed national development, a change in the national development model is needed. A comprehensive National Development strategy is needed, accepted by all major stakeholders. Such a strategy should be leaded by an inter-ministry coordination including the private sector; a purely market driven strategy is unlikely to reach the decarbonization objectives.
- Second-order effects of final demand measures need to be explored, in terms of resources and economic uses due to changes in the production structure, e.g. changes in automobile manufacturing arising from the introduction of electric vehicles, or the generalized electrification of energy end-uses by the household and service sectors.

National Circumstances

A central challenge for Argentina is to deeply mitigate its greenhouse gas emissions and at the same time achieve the United Nations' Sustainable Development Goals (SDGs). Exports, mainly from natural resources in both energy and agriculture sectors, played an important role in the country's growth and helped it to recover from the 2001 crisis: they account for a 20% of the share of GDP for the 2001 – 2015 period. For the year 2015, 11% of the GDP comes from exports. Remarkably, 36% of total grains production (oilseeds and cereals) are exported without further value-added steps, while 18% of total beef production went to external markets. (Argentine Government, 2019a).

In Argentina fossil resources contribute significantly to both primary energy supply (88% of the total in 2015) and for final consumption (77% of the total in 2015). Even while Argentina has a diversified electricity matrix (with some hydroelectric power plants, nuclear and intermittent renewables), most electricity is produced through gas and fossil fuel thermal power plants, and the final energy demand of the residential sector is mainly met with natural gas. Since 2010, the Vaca Muerta non-conventional oil and gas formation has boosted the country's fossil fuel independence while providing potential for additional export income. There is widely held vision in the country that the exploitation of these resources can contribute to economic development, the recovery of energy self-sufficiency and repair of the economy´s balance of payments (Dumas, J. y Ryan, D. eds. 2019, Government of Argentina, AGSE 2019). If deep decarbonization goals are to be met, however, this form of non-conventional hydrocarbon development, for both direct use and as blue (methane based with CCS) hydrogen, will require the technological and economic availability of carbon capture and storage.

In its Nationally Determined Contributions (NDC) Argentina has committed not to exceed 483 $MtCO_2eq$ of net emissions in 2030; this is a net reduction of 18% in comparison with its emissions trend in a business-as-usual scenario, but an increase of 33% compared to 2016 level. The large reduction efforts are in the energy and forestry sectors, and, on a secondary basis, in the agriculture, transport, industry and waste sectors.

According to the Argentine Government Secretariat of Environment and Sustainable Development (AGSESD), about 70% of the reduction effort in the proposed NDC baseline scenario is to be in the energy production sector and final energy demand (buildings). Yet the Agriculture sector of the economy has received much less attention for developing mitigation measures; together with the food industry, it accounts for 8% of Gross Domestic Product (GDP) in 2015. A brief mention of conditional measures is found in the National Action Plan for the Agriculture Sector and Climate Change, recently launched by the Argentine Environmental Secretariat (2019a). Reforestation stands out as the key lever in terms of increasing absorbed emissions. Transport accounted for 14% of fossil fuel combustion emissions in 2016 (Argentine Government, 2019b) and it is expected to double by 2030 compared to the 2015 level in a business-as-usual scenario. National climate pledges specify a few actions aimed mainly at improving efficiency in road freight transport, prioritizing railroads and public transport, among other unconditional measures that would not reverse the increasing trends (SESD, and MINTRAN. 2017).

Argentina has a National Adaptation Plan process developing mid-term (2030) sectoral strategies for achieving decarbonisation targets that are compatible with its revised NDCs targets, but early indications are these are still far from Deep Decarbonization Pathway (DDP) scenarios in terms of emissions reductions. These strategies are still under review and development, however, and are led by Argentinean Ministries and cover the energy, transport, health, industry, agriculture and livestock, infrastructure and land development and forest sectors (Argentine Government, 2019c).

The currently committed NDC measures (new ones are being developed for 2021) are insufficient to achieve the DDP objectives, especially those associated with final demand, and would imply greater concentrated efforts after that year. Getting to net-zero emissions of CO_2 across the energy and AFOLU systems is technically possible, but the proposed measures to achieve it are potentially highly varying in terms of the uncertainty level involved, potential rebound effects, their cost per unit emissions savings, and their technological maturity. Specifically, mitigation measures targeting the agricultural and livestock sectors, which account for close to half of GHG emissions in Argentina, are generally less developed and more uncertain than those targeting the energy sector. **Furthermore, the development of necessary massive carbon sinks to compensate emissions through afforestation still requires carrying out feasibility and environmental assessments.** Thus, achieving a 2 tonnes CO_2 per capita target for 2060/2070 **from the energy system**, to be balanced with negative emissions from reduced deforestation and afforestation, **has a high level of uncertainty** and poses significant challenges linked to Argentina´s productive structure and its national development goals regarding life quality, equality and energy security.

Project modelling methodology

Building 'backcasting' pathways from the 2050 goals to the present allows identification of the sequence of technical and socio-economic transformations required to reach a deep decarbonization long term objective as well as the underlying drivers, enabling conditions and required policy measures in the context of inertia, lock-ins, and innovation. To build such pathways, a combined qualitative-quantitative DDP method was used (Waisman et al. 2019) which is based on the complementarity between exploratory storylines and the quantification of the storylines as pathways through a set of numerical models: the LEAP (Heaps, 2016) energy model, the IMACLIM-ARG hybrid computable general equilibrium (CGE) model (Le Treut et al. 2019) and the FABLE land-use model (FABLE 2019). The combined tools make it possible to quantify the energy, land-use and socio-economic dimensions of the pathways. Two contrasting pathways were constructed to show how **deep decarbonization could be reached in Argentina** while **meeting other economic development goals,** both involving significant changes to the energy sector and economic system as a whole.

In the framework of the DDP LAC project, the Bariloche Foundation received specific assistance from the French research group CIRED to develop the IMACLIM-Argentina model, a new national version of the IMACLIM-Country model. This modeling capacity aims to study the impacts on Argentina's economic structure of actions to mitigate climate change, aka "decarbonization" (BID y DDPLAC 2019). The coupling between LEAP and IMACLIM at each step of simulation has been achieved which ensure consistency of the analyses. Concretely, key outputs from LEAP scenarios, such as energy content of the economy, the amount of investments for the power sector (by sectors) and the associated costs (basically capital and labour costs), are used to inform IMACLIM-ARG to be able to get an encompassing picture of the DD roadmap implications, and to capture the impacts of contrasted energy systems on the wider economy. Eventually, outputs on production growth levels from IMACLIM-ARG are then used to inform back the LEAP to adapt the energy scenarios. The procedure can be repeated as a loop until convergence of the models.

Using this modelling methodology, **two deep decarbonization scenarios have been built and evaluated** to be compared with the NDC trend scenario. In each of them, the necessary energy re-configuration to reach total emissions tending to 2 tonnes CO_2e per capita by 2050 has been explored. Nearly complete electrification of energy end uses is necessary to achieve the DDP targets in both scenarios. From the energy perspective, the scenarios mainly differ based on the use or not of Vaca Muerta's natural gas. Such use requires the adoption of carbon capture and storage (CCS) technologies. The other DD scenario relies on an intensive development of hydroelectric and nuclear resources instead. In both cases, significant development of variable renewable sources for electricity generation are required, reaching close to 50% of total electricity production levels.

The coupled framework enables the identification of both the macroeconomic impacts and the direct and indirect effects of the DD roadmaps built by the energy model. Indeed, the IMACLIM-ARG model allows highlighting the structural economic changes of contrasted DD strategies. It helps to understand the implications of the transition, according to the initial economic structure it has been given to it, on: GDP structure, sectoral employment and job creation, valued-added structure, and eventually on the enabling conditions in terms of financial or industrial strategies. Ongoing analyses show interesting preliminary results.

Despite a lack of precise updated economic structure data to inform IMACLIM-ARG at the base year, we went through the model calibration. To ensure greater robustness of the modeling framework, access to more recent national statistics would greatly aid this effort. More detailed information would also give an opportunity to disaggregate key sectors hidden into aggregates (such as heavy industries) and thus to deepen the sectoral analysis.

Key policy findings

One of the main conclusions of the Argentinian DDP study is that despite considering a significant set of mitigation measures in both the energy and the LULUCF sectors in the modeling, it will be necessary to resort to an increase in afforestation if it is desired to reduce net emissions to less than 2 tonnes CO_2 per capita per year. Although there is a high level of uncertainty and risk associated with this measure and no detailed feasibility analysis has been carried out yet, under adequate circumstances and an State-led integrated land use planning framework this could result in the preservation and increase of forest stocks (both natural and planted), with potential benefits from ecosystems services provision (e.g. soil erosion prevention, and water basin and ecosystems protection), which in turn can have tangible economic and health benefits for the society. These potentially positive outcomes also align with several National SDGs.

The scenarios modelled reduce the energy fraction of per capita emissions to practically zero by 2050. However, it is not possible to extend the goal to all sectors due to the impossibility of concurrently reducing non-energy land use CO_2, livestock methane (CH_4) and agricultural N_2O emissions. In this sense, **afforestation** acting as CO_2 sink arises as a requirement for Paris Agreement compliance, which requires net-zero CO_2 by 2050 for 1.5°C, and by 2070 for 2°C, and -50% CH_4 globally by 2030 to 2040. Remarkably, this highlights the distortion produced by the undifferentiated accounting of emissions from different sources and activities, an ethically disputable issue given that a country producing grains and livestock destined for export cannot achieve the required goals by compensating with its energy emissions. Additionally, the implementation of National policies in these primary sectors has been historically challenging and changes in production patterns and methodologies have been led mainly by short term productivity and market prices.

Concerning the energy system, Argentina´s DDP scenarios also highlight the **role of both hydro and nuclear power in zero energy emissions scenarios**. This is consistent with former sector strategies that provided the country with reliable power to stimulate development, increase energy security, reduce dependence on fossil fuels, help develop strategic industrial sectors and, in the case of nuclear power, also produce knowledge and technological spin-offs. Additionally, this strategy is **compatible with a higher share of variable renewable sources** in the electricity mix, development that would require an active and leading role of the National State.

Furthermore, from the preliminary analysis carried out with LEAP-IMACLIM, **DD strategies** based either on gas production with CCS or on the hydropower development together with nuclear energy **do not incur a significant macroeconomic cos**t but **do induce sizeable changes on the GDP structure, contrasted impacts across sectors in term of sectoral employment and production, and a strong shift in the sources of valued-added, compared to the NDC scenario**. A DD based on hydro and nuclear energy requires more investment which weighs more on GDP compared to a roadmap based on gas with CCS, but requires less offsetting with negative emissions in the long run. Both DD scenarios require sizeable construction which leads to an increase in job creation for the sector up to 2050. The energy sector production drops off but as it becomes more labor-intensive, jobs are created, especially in the DD scenario with hydro and nuclear development. These conclusions seem robust but they are also sensitive to the industrial strategies. The DD roadmaps should come with discussions and recommendations on the production location of the goods needed to meet mitigation goals. Relocations or relying strongly on imports could harm the economy. Additionally, other policies that couple the energy system to the productive one (such as the restructuring of the national automotive manufacturing complex towards electric cars) could be incorporated. This kind of analysis was not approached since there were no differences among both scenarios in terms of the final demand measures. However, the use and availability of economic resources or inputs required by these changes could affect the comparison due to second-order effects.

The costs of some zero carbon technologies, linked mainly to the energy sector, are dropping rapidly whereas business-as-usual is becoming more expensive and exposed to transition risks including asset stranding. Although there are potentially high costs to inaction, a comprehensive assessment of costs and benefits should compare the **long-term costs of different scenarios from a social point of view**, internalizing impacts on employment and health, avoided accidents, congestion, among other issues. This kind of analysis is very complex and highly uncertain for a long-time frame, but some insights can be achieved through integrated energy-economy modelling.

Regarding **key demand side measures**, improvements in refrigerators, air conditioning and lighting (light emitting diodes) respective efficiencies, as well as in thermal envelope (insulation), penetration of electric heat pumps for heating, and penetration of solar collectors for hot water, are outstanding in the household and services sectors. Additionally, given an almost total penetration of electric vehicles and already foreseen actions (NDC baseline) for improving efficiency in road transport of loads, prioritizing railroads and public transport are proposed as necessary actions for the transport sector.

Livestock and agriculture land use area projections imply that the sum of pasture plus agriculture remains constant. A reduction in emissions per head of livestock of 30% to 40% by 2050 is assumed compared to the trend scenario (achieved through diet modification and other measures, e.g. tannins, lipids, pasture management, food processing). However, there is still high uncertainty regarding the levels of enteric methane reduction and their permanence in time. Agriculture in turn, reduces its emissions by 20% to 30% compared to the NDC base line scenario, explained by increased crop rotation, incorporation of its residues into the soil, nitrogen use efficiency improvement (e.g. nitrogen release inhibitors, biological nitrogen fixers) and increasing the share of cereals relative to oilseeds.

Finally, the development of Vaca Muerta non-conventional oil and gas deposits clearly conflict with DDP strategies unless carbon capture and storage and/or blue hydrogen production were to be used. However, since it is considered to be a key to Argentina´s long term development strategy, it cannot be disregarded unless a suitable alternative can be found. This implies that in order to meet the goal of zero deep decarbonization energy emissions while continuing the development of Vaca Muerta, international financial efforts supporting local research projects and the promotion of pilot CO_2 capture and storage projects are necessary.

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COLOMBIA
OPTIONS FOR MID-CENTURY DEEP DECARBONIZATION STRATEGY

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Key messages

- We find that an extension over time of current and announced policies is insufficient for achieving the desired outcome of reaching carbon neutrality by 2050. Deep decarbonization requires major changes to be fully implemented by 2050. There is still time to plan a smooth and economic transition. Lowering ambition in the short term might not only reduce the effectiveness of decarbonization but also increase unnecessarily the transition costs and reduce the benefits.
- To help inform revision of Colombia's NDC, Colombia should construct its LTS within the context of its unique circumstances and societal goals while meeting the goal of net-zero emissions later this century. Poverty alleviation requires use of currently available resources to support the early transition towards a low carbon economy.
- Energy efficiency is important yet decarbonization is mainly reached using cleaner energy, i.e. switching to very low and zero carbon fuels. The transition could be smooth if it starts soon and with incremental and sustained efforts.
- Electricity will be the dominant fuel for decarbonization. Hydro, wind, solar and sustainable biomass-based generation will need to provide most of the power demanding the exploration of grid improvements and backup options (power to gas, batteries, pumping hydro, demand response programs).
- The power sector will increase its activity and is required to do the transformations that enable it to provide a reliable, affordable and net-zero emissions service. Anticipation is key to take advantage of the new business possibilities within this sector. We have 30 years to plan, build and design the operation of a larger than now and net zero CO_2 emissions power system. We shall not forget, however, that 30 years might be the useful life of a new power plant, so planning the next few years investments is key for the longer-term goal.
- In a deep decarbonization scenario, there is an increase in the production of agricultural products (including bioenergy) and exports. Stopping deforestation is a must and there is the need to enable lands to produce additional food and biomass by intensifying crops and cattle.
- International markets of oil and natural gas will still be active by 2050 with lower demands and highly uncertain prices. Decarbonization in Colombia will not eliminate domestic oil and gas industries but their competitiveness by mid-century would depend largely on international circumstances.
- Transportation has two lines of action towards decarbonization. Firstly, public transportation needs to support the growing passenger demand in the upcoming years, eventually switching to net-zero emissions vehicles. Private modes should stabilize its participation at current levels, and also switch to net-zero emissions vehicles. Overall, the transportation energy mix needs to be transitioned to the use of biofuels of second and third generation, electricity and hydrogen, with a focus on the latter two energy forms in urban settings due to local air quality needs. Regarding freight, there is the need for using alternative modes such as rail and water transport lowering the emissions by introducing heavy duty trucks powered by advanced biofuels, LNG and hydrogen.

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Where Colombia stands

Like all countries around the world, Colombia must construct its LTS within the context of its unique circumstances and societal goals, and in the short term with a mind to recovery from the COVID pandemic. Colombia's current economic context is characterized by a high share of the services sector in GDP, followed by lower shares for manufacturing and agroindustry activities, and mining. However, both the external and fiscal fronts have a marked dependence on fossil fuels exports. Total Colombian emissions in 2014 were 214.3 Mt CO_2e, which makes the country relatively low per capita emitter (4.56 ton CO_2e per capita). The Agriculture, Forestry, and Other Land Use (AFOLU) sector is the largest emitter with net emissions amounting to 50% of the total, followed by energy, which represents 39%. Within the AFOLU category, land use change is responsible for 60% of the emissions while, within energy, the largest emitter is the transport sector, which represents 36% of the category's emissions (IDEAM, et al., 2017).

Controlling deforestation is key for lowering emissions. The country has large areas of unmanaged forest, which raises concerns about deforestation that accounts for the vast majority of land use change and associated emissions. On the other hand, **current electricity production has relatively low emissions** due to a large share of hydroelectric production [(IDEAM, et al., 2017; UPME,2016; XM, 2015), and the country shows low per capita energy consumption. However, even at moderate economic growth rates, within the span of the following three decades Colombian GDP should increase at least two-fold and the energy sector will grow substantially. As for other countries, broader concerns about prosperity are the ultimate goals for Colombia and, to be successful, mid-century development strategies must identify appropriate synergies between climate protection and a prosperous and sustainable future.

Goal and scope of the study

The development of mid-century strategies is challenged by the uncertainty associated with understanding the future several decades from now. It is also challenged by the complexity of the underlying technological and societal systems that must evolve to reduce emissions and limit temperature change. Despite this fact, there is increasing evidence that a net-zero emissions is possible.[6] While there is no way to fully manage these challenges, formal energy-economy, integrated assessment, or similar models have been used extensively to produce self-consistent scenarios of the future and to inform planning (Winkler et al., 2017; Raubenheimer et al., 2009; Winkler,2009). With such an aim, in this study we use the Global Change Assessment Model (GCAM) to develop three representative pathways toward deep emissions reductions by mid-century in Colombia.

We explore what might happen: 1) under Colombia's current policy trajectory, 2) in a context of a 30% reduction in CO_2 emissions by mid-century, and 3) in a 90% reduction scenario (the last two ones are consistent with two-degree and 1.5 degree rises in global temperatures, respectively). These stylized climate policy scenarios are not intended to serve as high-fidelity representations of how Colombia's low carbon development strategy will be. The Colombian LTS would potentially consist of hundreds of measures implemented across numerous sectors and sub-sectors. However, as they will have to be guided by overarching, common sets of strategic and articulated interventions, our goal is to contribute to identify and delineate them in a way that is clear in providing insights for decision-making at the heart of long-term climate and economic planning.

6 https://publications.iadb.org/en/getting-net-zero-emissions-lessons-latin-america-and-caribbean

Main findings

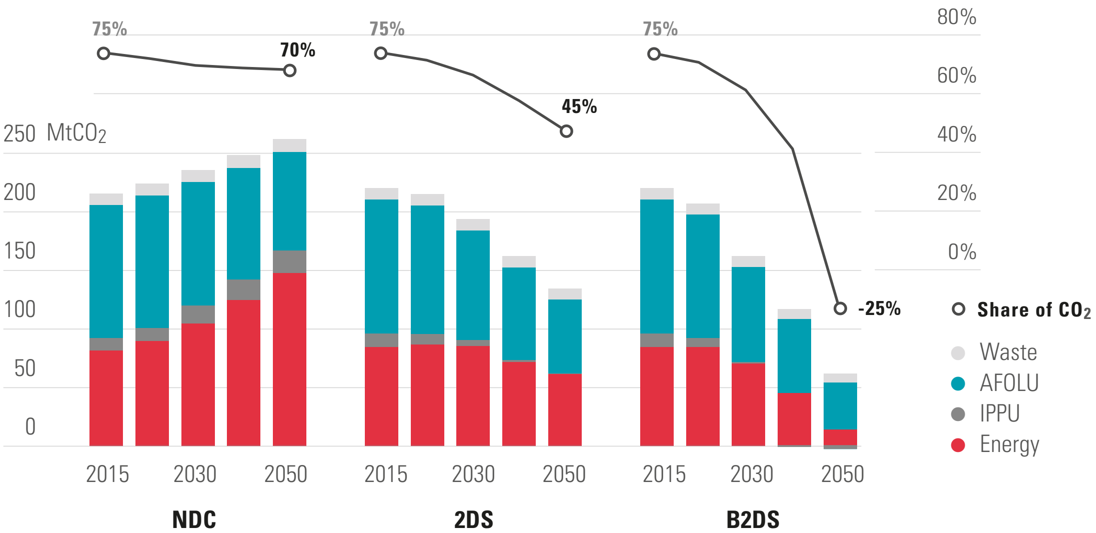
We find that an extension over time of current and announced policies is insufficient for achieving the desired outcome of reaching carbon neutrality by 2050. In fact, despite these efforts, emissions will continue to grow if no additional and more ambitious measures are implemented. **We also find that the distinction between CO_2 and non-CO_2 gases are important in the context of countries such as Colombia, where the agricultural sector is economically relevant, both currently and as an engine for future growth.** Indeed, agricultural emissions are only modestly reduced across our three scenarios, as the sector must provide for food, intermediate, and energy demand in a context in which international trade is important. This also leads to significant increases in agricultural land, that the country has the potential to accommodate without increasing deforestation (which requires appropriate agricultural intensification).

Early action is required to successfully reach this mid-century goal. Although the AFOLU sector is currently the largest source of emissions in the country, mitigation efforts are required in all the other sectors. Deforestation must be controlled, and energy sector CO_2 emission and their growth should be addressed early by any LTS. This mandates that energy be generated by non-emitting sources, that end users switch as much as possible to energy carriers that will support the use of these sources (e.g., electricity, biofuels), and that energy use is constrained as much as it is feasible. Rapidly declining electricity emissions that ultimately serve as a sink for CO_2, using bioenergy coupled with carbon capture and storage (CCS) technology is a possibility. However, **CCS could be explored as an option with large caution due to the uncertainty of its future commercial availability**. The country should not rely on the availability of CCS and such expectations should not stop the required transformations to have a 100% renewable power sector.

Clean electricity is required to support energy consumers. Clean electricity would provide typically difficult-to-decarbonize sectors, such as freight transportation and industry, more room to limit their emissions. Recent advances in battery technology also make feasible for the transport sector, including

Figure 18. Yearly Colombian greenhouse gas emissions and share of CO2 in the three modeled scenarios

Current policies (top left), 2°C Scenario (top right) and 1.5 °C Scenario (bottom).



freight, to be another potential component of Colombia's decarbonization strategy, intimately linked to electricity sector emissions reductions.

As expected, final energy demand grows rapidly, driven by population and income growth. Emission reductions are reached by improvements in energy intensity as well as in the carbon intensity of energy used. Reductions in energy intensity primarily reflect technological changes such as more efficient devices, use of public modes for passenger transportation, modal shifts for freight, but also some changes in end-user behavior. Nonetheless, these improvements, while sustained, are not the main driver of change. This role is reserved for the carbon intensity of energy, through less carbon intensive or renewable sources substituting for carbon intensive fuels.

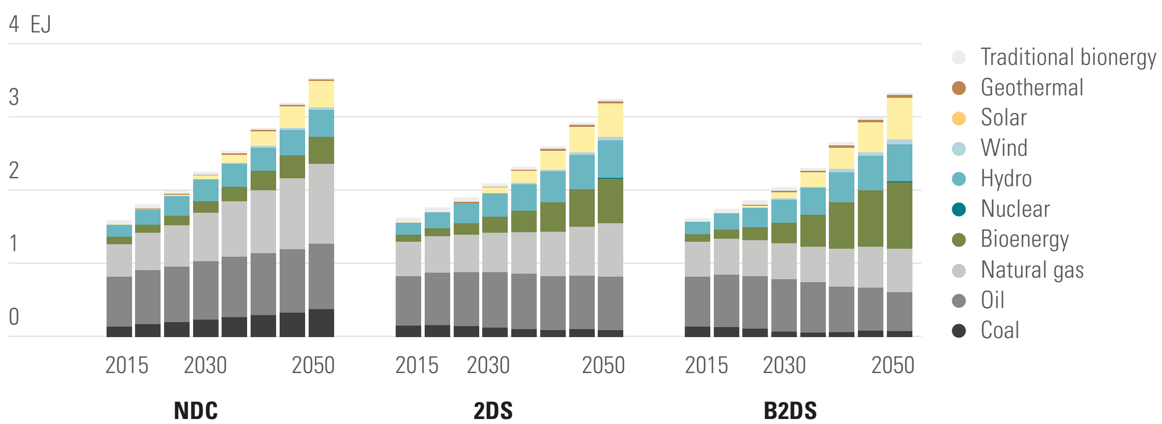
Decarbonization implies major adjustments in the fuel mix. Sources include solar, wind, hydroelectric, geothermal, nuclear, bioenergy, and fossil or bioenergy power coupled with carbon dioxide capture, utilization, and storage (CCUS). While the mix cannot be foreseen with certainty today, our results allow for pointing towards three important issues in the Colombian context: the role of renewable resources; the role of second and third generation biofuels, given the emphasis on the agricultural sector and the potential to use bioenergy both domestically and internationally; and the manner in which fossil resources might still be deployed in the Colombian energy mix and the implications for CCUS.

For decarbonization to take place, **the share of renewables in the primary energy mix needs to more than double by 2050** and it mainly occurs through substantial increases in bioenergy utilization and solar power. Hydroelectric power keeps its importance but increases at a slower rate through time. The increase in solar and wind penetration and the substantial use of biofuels calls for investments and strategies to manage an electricity grid that is more dependent on intermittent resources and long-term planning, particularly in the context of a changing climate that could impact the seasonality and availability of hydroelectric power to balance the expanded variable renewables fleet. On the other hand, fossil fuels are a critical piece of the puzzle, not only because of their role in the domestic energy system but also because of their current and project economic importance. In this case, the future of the fossil fuel industry may depend, to a large degree, on the international market demands and prices and on the availability and cost of CCUS technologies that are currently under development (and possess a high uncertainty on it effectiveness and techno-economic feasibility).

The potential use of CCUS calls for increased understanding of the potential for, and the limits to, CCUS in the future Colombian energy system (Williamson, 2016). Any alternative will require greater use of other low emissions electricity sources, including solar, wind, bioenergy, and potentially

Figure 19. Primary energy consumption by energy carrier in the three modeled scenarios

Current policies (left), 2°C Scenario (center) and 1.5 °C Scenario (right).



nuclear power, as well as a more aggressive use of bioenergy and electricity in transport and industry. Electricity will be the dominant fuel for decarbonization, while natural gas consumption declines, and coal is virtually eliminated in end use sectors. Therefore, final energy sectors should avoid expanding use of natural gas and coal, and instead focus on increases in electricity and liquids from biomass to be on track for reaching climate stabilization.

Transportation is currently the largest energy sector contributing to CO_2 emissions, and activity is expected to grow. We estimate the road transportation will grow 2.2 times between 2015 and 2050, while decarbonized transport services will need to be provided for public transport systems that grow to serve over 70% of total road mobility demand by 2050 (reversing the trend toward private vehicle use as income per capita increases). Furthermore, we estimate by 2050 64% of the public transport systems need to be powered by electricity, while the rest of power will be a mix of natural gas, fossil liquids, and biofuels.

Strategies to address deforestation are a critical component of any Colombian LTS. For this study, given the complexity of the underlying dynamics of deforestation, its behavior was developed exogenously to GCAM. The deforestation trajectory was selected to remain consistent with the land requirements for

Figure 20. Power generation by source in the three modeled scenarios

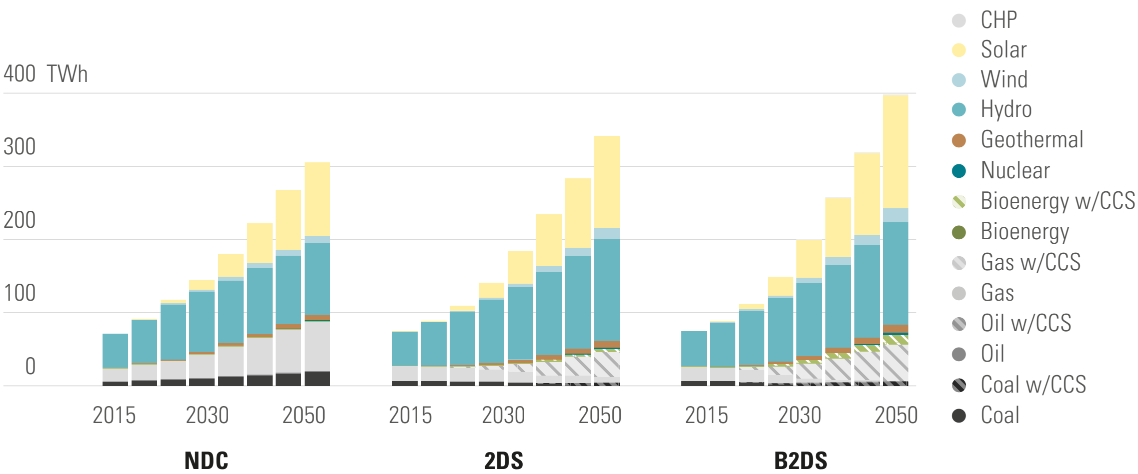


Figure 21. Yearly motorized km travelled by passengers and energy mix for passenger transport in the 1.5 °C Scenario

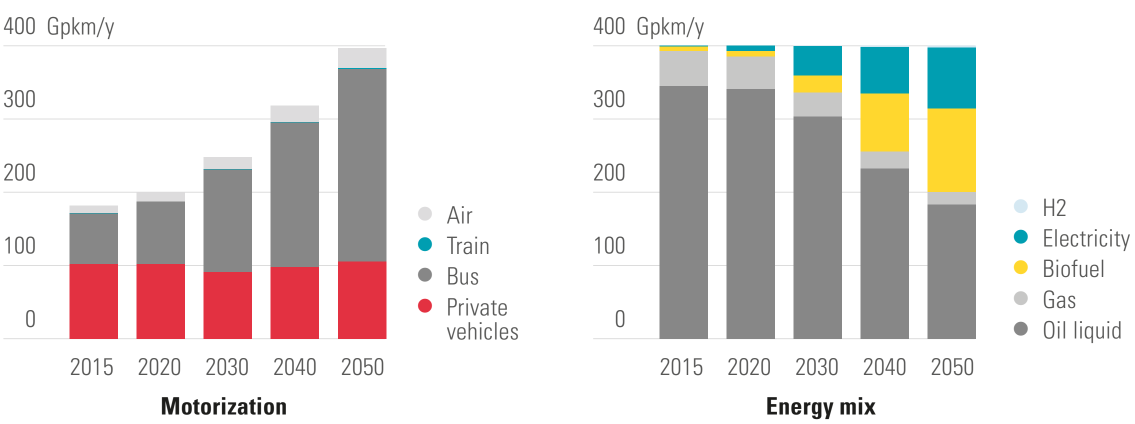
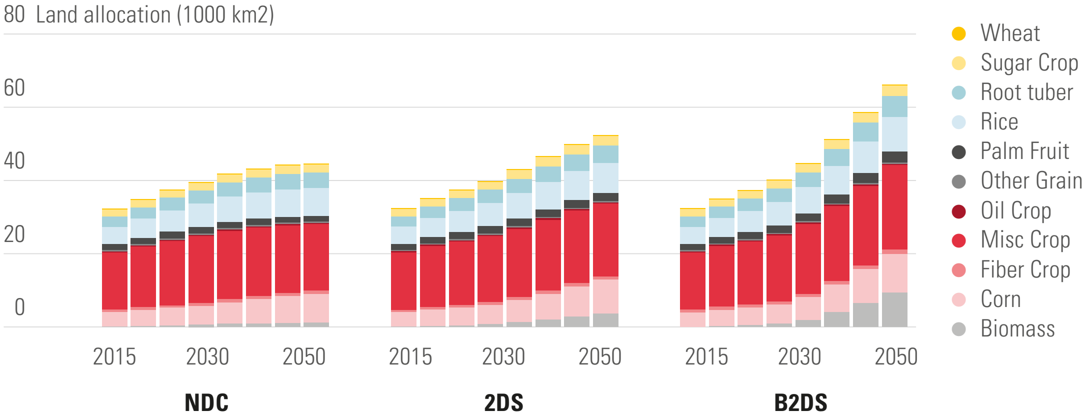


Figure 22. Agriculture land allocation by crop in the three modeled scenarios

Current policies (left), 2°C Scenario (center) and 1.5 °C Scenario (right).



agricultural and bioenergy production. We project a large increase in agricultural activities and their associated land demands because of higher production of biomass for energy as well as food. Such a development would be consistent with an improvement in rural activities and a broader economic opportunity for the national economy. However, enabling additional land for food and biomass production while reducing deforestation, and even increasing reforestation, is a fundamental challenge.

Intensification of livestock production is key for freeing up areas that can be used for increased crop production, with an emphasis on biomass. Moving from a current animal density of about 0.8 heads per hectare to 2 heads per hectare could free about 12 million hectares for other agricultural uses (allowing for more than doubling currently planted areas), and also helping to end pressure on natural forests in some critical regions and to increase afforestation and ecosystem restoration. Further development of appropriate livestock technologies, provision of technical assistance to ranchers, and streamlining and strengthening marketing practices, can be important tools in achieving this goal. Reducing deforestation and making better use of land resources for agriculture (a key component for improving rural household income) may be facilitated through appropriate land planning processes and agricultural intensification (especially in the livestock sector). This allows for a partial reallocation of agricultural activities and for increasing production in a manner that is both compatible with zero net emissions and with food and intermediate goods affordability.

Conclusions

The scenarios in this study show that current and announced Colombian policies are not compatible with compatible with deep decarbonization. Following them could imply technological choices that would raise the risk of stranded assets and increase the challenge of climate mitigation.

Planned decarbonization trajectories with early actions might reach the climate stabilization goal, enhance the national economy, and help Colombia reach the SDGs at the same time. In terms of timing, the only required near term action indicated by all the explored scenarios is that there be quick phase out of coal for internal consumption, indicating a just transition strategy for this sector should be implemented as soon as possible. All the other transformations give more space for the transition, but there is no time to waste. Other than coal, there is still time to use current fossil fuel capital stock and resources within the length of their useful lives . However, new investments would require to be done acknowledging the mid-century decarbonization goal. Clear signals to markets are required regarding the Colombian commitment to the mid-century deep decarbonization goal. This clarity would unlock new business opportunities such as the intensification of the agricultural activities, the deployment of an advanced biomass industry, the development of a more advanced and modern power sector, opportunities for the local industry in the development of the electromobility and its infrastructure, among others. A planned pathway towards deep decarbonization is not incompatible with the successful completion of current business (after the end of asset and projects useful life) and might imply new business opportunities for the mid and long term. This might be a way to couple current efforts for poverty alleviation with longer-term options for sustaining these efforts. None of them should be dismissed, poverty needs to be alleviated now and permanently.

The scenarios in this study articulate several key actions and issues that are of sufficient potential importance to warrant further consideration as part of a LTS development. These include the following: (1) stopping deforestation, including enabling lands to produce additional food and biomass by intensifying crops and cattle; (2) use of solar and wind power in electricity generation with associated exploration of grid improvements and seasonal backup; (3) electrification of transportation and industry; (4) the potential to increase public transportation as a means to constrain transportation emissions and enhance urban lifestyles; and (5) the critical potential role of bioenergy in transportation, electricity generation, negative emissions, and possible exports, and its broad implications for agriculture and energy policies and dynamics and, with high caution due to the inherent uncertainties (6) CCUS as an option to allow for continued use of natural gas in electricity generation and potentially to support bioenergy with CCS.

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COSTA RICA
GETTING TO NET-ZERO EMISSIONS: SUMMARY FOR POLICYMAKERS ON THE LESSONS FROM THE ENERGY AND TRANSPORT SECTORS

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Getting to net-zero is necessary to limit the temperature rise to 1.5 °C, it is technically possible, and it brings benefits to development.
The Paris Agreement establishes a mechanism to fight climate change by contributing to mitigation of Greenhouse Gas (GHG) emissions caused by anthropogenic activities [1]. Starting in 2020 and every 5 years thereafter, countries of the United Nations Framework Convention on Climate Change (UNFCCC) must update their progressive commitment towards decarbonisation through their Nationally Determined Contributions (NDCs) for holding global warming well below 2°C above pre-industrial levels while pursuing efforts to limit it well below 1.5 °C. While NDCs will support the transformation, countries are encouraged to define Long-Term Strategies (LTSs) to guide this transformations with economic and social goals [2].

Reaching net-zero emissions is technically possible. There is an international agreement that net-zero emissions of carbon dioxide (CO_2) by 2050 and a deep reduction of other GHGs can be accomplished through actions around four central pillars: (i) producing zero carbon electricity (and other liquid and gaseous fuels); (ii) undertaking massive electrification and switching to net-zero fuels; (iii) increasing the share of public and non-motorized transportation; (iv) halting deforestation and protecting and regenerating natural carbon-rich ecosystems. Technological solutions are already available for each pillar.

Costa Rica has made progress. Different policy packages put in place have resulted in an almost 100% renewable electricity [3] and 60% of the national territory being covered by forest [4} (compared to less than 30% in the 1980s). These two milestones represent the first two pillars of the country's decarbonization process.

Efforts are still needed in the energy and transport sectors. The latest GHG inventory (reported to the UNFCCC5) highlights that the energy sector accounted for 67% of the country's gross emissions (10.88 $MtCO_2eq$), with transport representing 51% of the total. This not only produces health issues, but also serious traffic congestion and accidents. Thus, decarbonizing through limiting urban growth, promoting a modal shift to non-motorized transport, reducing demand due to digitalization of jobs and teleworking, and adoption of low-emissions technologies like electric personal and public transit vehicles are key strategies towards the mid-century goal.

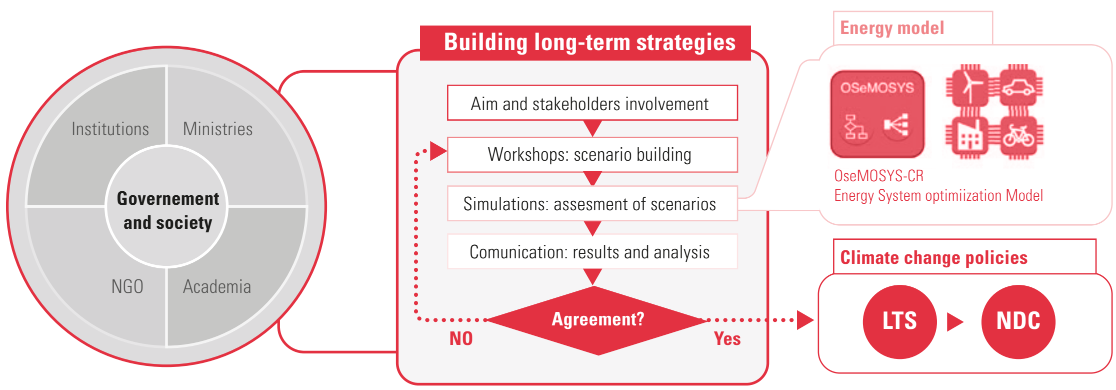
Measures in other sectors will also be needed to meet the mid-century target. Improvements in efficiency and reduction of waste across all sectors, particularly from energy and food consumption, and switch to less carbon-intensive industrial processes, building materials and diets, will also help meeting the 2050 target.

A regional project supported visioning the Costa Rica of mid-century. Costa Rica took a leading role in the Deep Decarbonization Pathways in Latin America and the Caribbean (**DDPLAC**) project. Coordinated by the Institute for Sustainable Development and International Relations (IDDRI) and the Inter-American Development Bank (IDB), the project provides a framework for the definition of an LTS to six Latin American countries emphasizing the need for stakeholder consultations and co-identification of mitigation measures [1]. The Costa Rican team was formed by members of the University of Costa Rica (UCR), the Royal Institute of Technology (KTH) and the Directorate of Climate Change (DCC) of the Ministry of Environment and Energy. The team developed and used an energy system optimization model (OSeMOSYS-CR) to support the national strategy process.

Efforts made during DDPLAC supported the creation of the LTS. The National Decarbonization Plan (NDP_ of Costa Rica [6], launched in early 2019, maps out a comprehensive transition to net-zero emissions by 2050. Designed by the Climate Change Directorate (DCC) through a backcasting participatory process illustrated in Figure 23, the NDP was communicated to the UNFCCC as its long-term, low level GHG strategy. The NDP describes a transformational change structured in ten lines of axion -transport, energy, buildings, industry, waste and AFOLU sectors- with policy targets defined using the analytical framework of the DDPLAC project.

A structured stakeholder consultation approach was deployed to produce the LTS. The process to produce the LTS started with a stakeholder engagement process as an essential step in the design, assessment, and implementation of decarbonization pathways. This ensured that the perspectives of all the relevant actors were considered while accounting for different development goals, understanding what changes could be viable, and what the barriers are to decarbonizing the country. This engagement also strengthened the ownership of the LTS amongst stakeholders and their support during implementation. The process consisted of meetings to define common aims and engage with stakeholders. This led to structuring the Plan into ten lines of actions, eight cross-cutting strategies and three stages for the implementation. Through a participatory process, a scenario building exercise was carried out in which narratives, formulation of technical

Figure 23. Integration of Government and society in the backcasting participatory process



considerations, and restrictions were defined. Then, the assessment of scenarios involved the modeling of targets within OSeMOSYS-CR (and a precursor model) for the energy sector and simple linear models for other sectors[7]. Finally, the DCC provided feedback to stakeholders through the presentation of results which not only included the main outcomes, but also methods, techniques, and sectorial results to ensure a transparent communication of results through graphs and tables.

7 OSeMOSYS-CR contains the entire Costa Rican energy sector based on the best available data. The model includes cost and capacities of multiple technologies such as power plants, vehicles, buses and variables such as the sale of fossil fuels and electricity, or the relation between the average distance traveled and energy consumption for transport. A module for co-benefits, linked to fossil fuel uses, calculates the effects on health, congestion, and accidents.

A systematic approach to produce decarbonization pathways was stablished. The narratives and other inputs provided by stakeholders were then modeled in OSeMOSYS-CR. A decarbonization scenario towards mid-century was developed: a 1.5°C scenario that is compatible with a goal of net zero emissions by 2050. Costs and benefits were compared to a business-as-usual (BAU) scenario that projects the

Figure 24. Key objectives in the decarbonization of the energy sector in Costa Rica

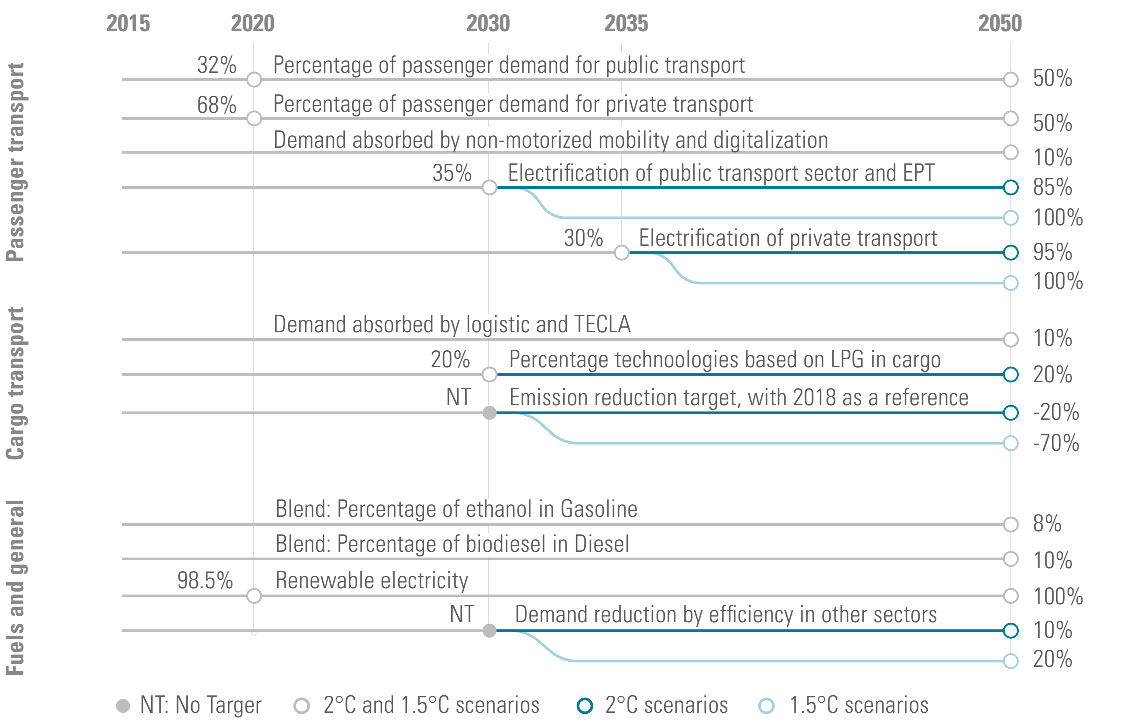


Table 1. Main strategies in the decarbonization pathways in the Costa Rican energy sector

Urban planning and mobility	Switching fossil fuel technologies	Switching energy carriers
✔ Costa Rica implements a mass rapid transport system with an Electric Passenger Train system as a backbone. ✔ A modern public transport scheme is deployed. ✔ Urban planning practices, including densification of the city, building bikeways, and the integration of environmental elements that promotes walkability and sustainability. ✔ The use of light-duty vehicles is reduced, and modal shift occurs towards public transport. ✔ Teleworking and the digitalization of businesses reduces energy consumption improves efficiency.	✔ The import and purchase of electric vehicles, not only for private use, but also in buses and cargo occurs as a result of better market conditions and incentives in place. ✔ The Limón's Electric Cargo Train (TELCA) operates with a load transfer center for the main cargo route in the country to reduce carbon emissions from heavy freight. ✔ Flexibility, intelligence, and resilience of the electric system is consolidated under the concept of smart grids.	✔ Biofuels produced locally are in place and they help to replace imports promoting local business. ✔ Green hydrogen (from electrolysis), particularly for heavy duty vehicles (cargo and buses), is in place after 2030 to reduce emissions from the sector.

behavior of the emissions without considering policy interventions (i.e. following the historic trends). The main strategies in the 1.5°C scenario are described in **Table 1** and the objectives presented in **Figure 24**.

Getting to net-zero is possible in the transport and energy sectors of Costa Rica. The modeling of the objectives (**Figure 25**) allows understanding that emissions in the energy and transport sectors can be reduced by mid-century by 8.4 $MtCO_2eq$ (**Figure 26**). The reduction occurs primarily through a replacement of fossil fuels used in the transport sector with renewables in the energy mix that will then feed the electric vehicles, electric buses and enable the electrification of other sectors.

A deep decarbonization scenario implies modal shifts and reductions in distance travelled. The decarbonization pathway for Costa Rica involves a transition to public transport that represent from 45% to 70% of motorized kilometers travelled by 2050 compared to often significantly lower figures (down to 30%) in scenarios without climate change policies. The Plan envisions that, by 2050, public transport should cater for most of the demand in metropolitan areas, and that non-motorized modes (including walking and cycling and reduced demand due to the digitalization of jobs and teleworking) should increase their contribution to 10% of mobility by 2050.

New renewable power plants and higher efficiency

Figure 25. Annual emissions in the energy sector

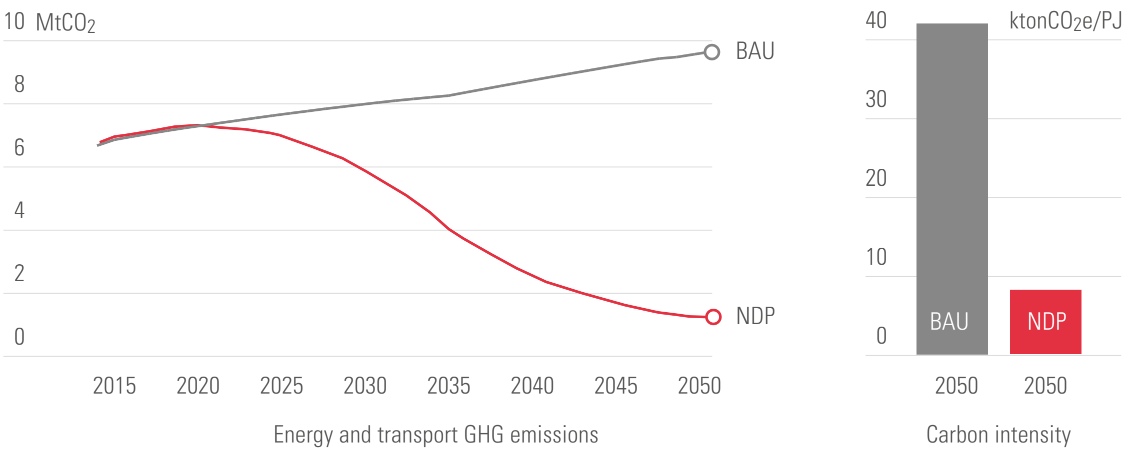
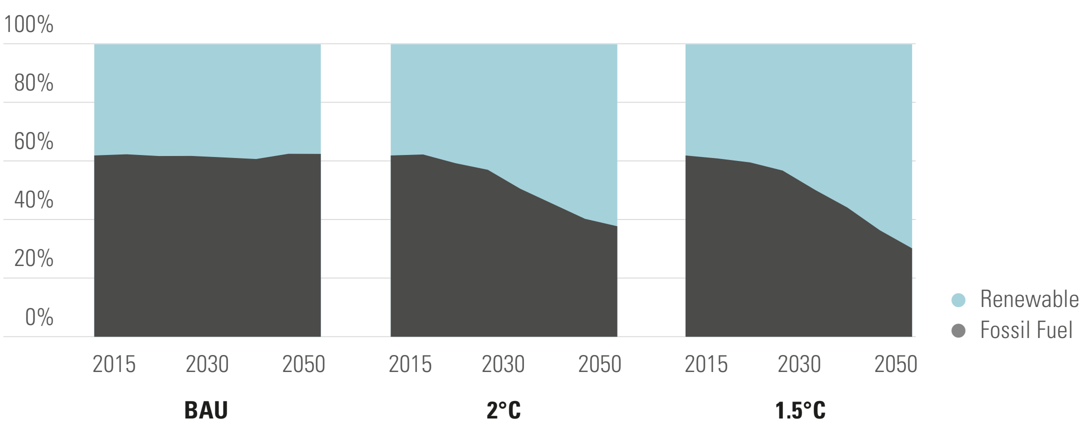


Figure 26. Distribution of energy



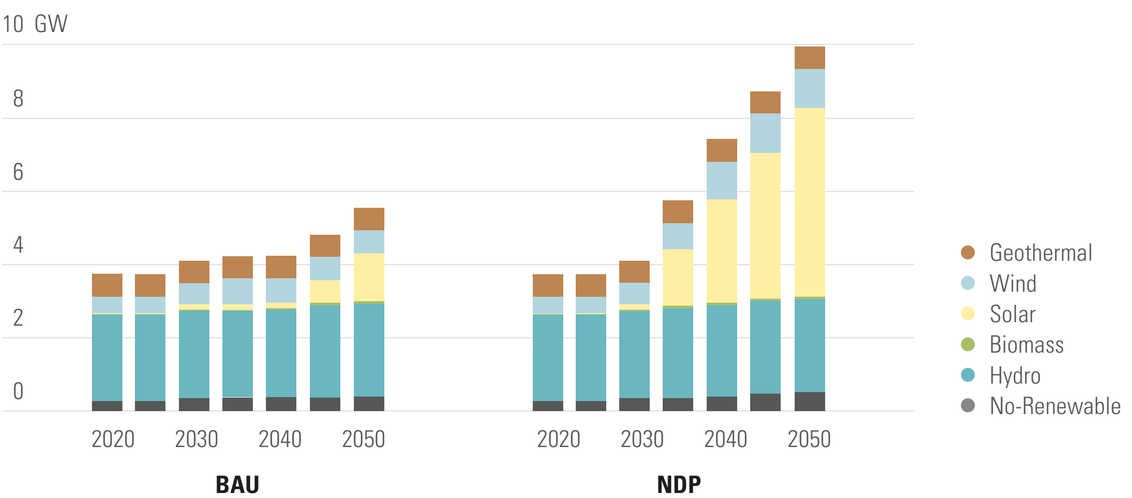
to produce electricity will enable the electrification. The Expansion Plan of the Generation defined by the Costa Rican Institute of Electricity (ICE in Spanish) runs until 2034. Some plants will be built to meet the growing existing demand, currently with a 2% growth approximately. The electrification of the transport sector, however, may require additional plants. More efficient processes to produce electricity may also be needed to support this transition. Compared to the BAU scenario in 2050, the study found that a deep-decarbonization requires about 4.4 GW of additional installed capacity (**Figure 27**). Their operation is, nonetheless, needed primarily after 2035 given that the massive deployment of electromobility starts to take place. This implies that investments may not be significant as the cost of low carbon generation technologies are expected to be much lower in the future[2,7].

The decarbonization process requires investments that are compensated with reduced operational costs. Deploying zero or low emission technologies may lead to higher investment costs today, but their operation is in almost all cases cheaper. In addition, the costs of zero carbon technologies are dropping rapidly whereas business as usual is becoming more expensive and exposed to transition risks including asset stranding. The cost of batteries for electric vehicles has also seen a six-fold reduction in just eight years, which is expected to continue. Compared to the BAU scenario, the study finds that the decarbonization requires additional investments of US$ 26.7 billion by 2050 that are contrasted with savings of US$ 29.7 billion by the same period [**Figure 28**], thus leading to a positive net financial benefit of US$ 2.9 billion (approximately 5% of current Costa Rica's GDP).

Co-benefits could exceed the decarbonization investment costs. Decarbonizing the transport sector brings opportunities to improve mobility, reduce local air pollution, and improve the quality of life. Time lost in congestion and the cost of accidents is also an expensive problem. In Costa Rica, it is estimated that time lost due to congestion, accidents, and the health impacts of local air pollution cost the country 3.8% of GDP annually[8]. Moving to efficient public transport systems and to electromobility vehicles could be one of the greatest opportunities to support the transition to net-zero emissions while bringing substantial benefits to the economy and society. An effective urban transport system based on electric buses can cut congestion, accidents and local pollution while taking advantage of renewable electricity and saving money. Results from the DDPLAC team[8] highlights that accounting for these aspects can increase the economic benefits of decarbonizing the transport sector to about US$ 20.6 billion [**Figure 28**(c)], which

8 Supported by another project that assesses the cost and benefits of decarbonizing the transport sector.

Figure 27. Installed capacity per technology and scenario



represents almost 35% of current GDP.

Investments made today enable the benefits in the mid and long-term. The timeline of these socioeconomic benefits (**Figure 29**) indicates that investments surpass savings in the short-term (2020-2030). The

Figure 28. Cost comparison by scenario

Values are discounted at 5% up to 2050

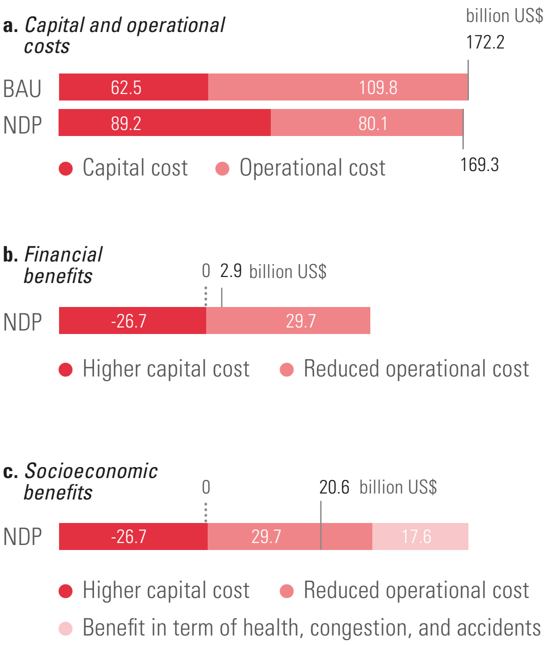
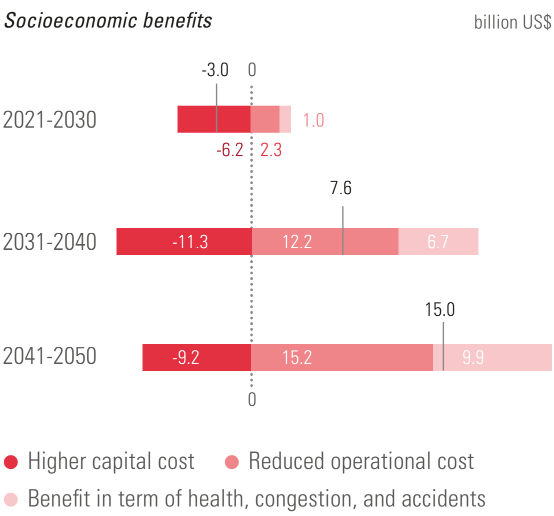


Figure 29. Timelines of socioeconomic benefits.

Values are discounted at 5% up to 2050



investments are related mainly to the initial roll-out of electric vehicles in the private fleet, the electrification of light freight transport, the first phase of the passenger train deployment, and new renewable power plants. While investments are still needed in the mid and long-term, operational savings (highly related to lower fossil fuel consumption) always compensate capital costs; thus, bringing net financial benefits. In these two periods, the investments in low carbon freight trucks are predominant. Furthermore, it includes the second phase of the electric passenger train and the transition to more efficient public transport, while continuing the electrification of buses and private vehicles. In the energy sector, renewable energy infrastructure continues to support the technological transition. If we add up the benefits in terms of health, congestion, and accidents, the socioeconomic benefits in the mid and long terms represent almost 13 and 26% of current Costa Rica's GDP; thus highlighting that benefits are greater as the mid-century goal is reached.

The decarbonization process is likely to create winners and losers. The transition towards cleaner energy sector can have an impact on consumers, workers, communities and businesses related to phasing out or downsizing economic activities that are inconsistent with net-zero emissions, e.g. the commercialization of fossil fuels. The short-term impact of removing energy subsidies or introducing environmental taxes that increase the cost of food and basic services are also important issues. Anticipating, minimizing, and compensating them by targeted policies and complementary measures are as critical. Furthermore, international evidence suggests that the social acceptability of reforms requires the consultation of stakeholders and communication campaigns before implementing reforms.

Fiscal revenue will also be affected. Fiscal sustainability is essential to the political feasibility of the reforms needed for transformational approaches. Government income from the transport sector represents about 20% of the total revenue in the country **[9]**. The adoption of electric vehicles will reduce revenues from gasoline and diesel taxes. With Costa Rica's LTS in place, the government is now able to anticipate these changes, which are being studied by the country with support of the DDPLAC team to allow for identification of alternative fiscal measures to be planned and implemented. To manage the potential impacts, the Plan can be used to progressively adjust the rate of taxes on gasoline, electricity and vehicle ownership and operation based on the targets in the Decarbonization Plan.

The LTS leads the development of Costa Rica. Costa Rica committed to decarbonize its entire economy by 2050. This transformational change will need to overcome multiple challenges. To study them, local and international experts will be needed to produce technical studies that support the transition, bringing robust evidence of the most cost-effective path towards a decarbonized Costa Rica in 2050. The NDP also places the decarbonization at the heart of multiple government and autonomous institutions, which will need to adapt their plans to the new normal. Coordination between institutions to coherently articulate efforts becomes critical. Fortunately, there is a great opportunity today to execute the so-called green recovery post-covid which will bring multiple additional benefits for its population.

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ECUADOR
GETTING TO ECONOMY-WIDE NET-ZERO EMISSIONS

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Key policy messages

- Ecuador's NDCs are not enough to set the country in a pathway towards a well-below 2°C world. Ecuador still needs a long-term integrated strategy (LTS) aligned with the Paris Agreement.
- International cooperation could help create the enabling conditions for moving in the direction of deep decarbonisation through financing, training, technology transfer and institutional capacity building.
- Diversifying the electricity generation system with non-hydro renewable energy is key to reduce the dependency on large hydropower generation (5 GW today), which could worsen in climate change scenarios with less precipitation. Up to 2050 the power system would require a total 4.4 GW of solar PV, 3 GW of biomass-fired thermal power plants with carbon capture and storage (BECCS), 900 MW of on-shore wind and 500 MW of geothermal plants. It all adds up 9 GW, which is 17 times more than 2020 non-hydro installed capacity. Additional 3GW of hydro power plants would be required up to 2050. Total installed capacity in 2050 would be 18 GW.
- Developing a bioenergy industry is necessary for deep decarbonisation. Planted crops may be sustainably managed to provide woody biomass to bio-refineries and thermal power plants. Around 500 thousand hectares of sustainably managed planted forest would be required by 2050. In 2015 forest area in Ecuador was 12.8 million hectares (51% of the continental territory).
- Ambitious reforestation could avoid the dependence on risky and expensive carbon capture and storage (CCS). Reforestation and conservation of additional 300 thousand hectares, in comparison to the 2015 base year, would provide enough negative emissions to avoid the deployment of an additional 900 MW of BECCS.
- Electrification of passenger transportation is crucial to reduce emissions. By 2050 70% of buses, and 33% of private cars would need to be electric. Around 10% of passenger transportation demand may be supplied in a non-motorized way (walking, biking, skates and skateboards) in urban cities. This requires actions to improve urban planning and municipal integrated transport systems.
- Emission reduction in freight transport is challenging, it requires electrification and use of advanced bio-fuels. By 2050 40% of light and medium trucks fleet could be electric, while only 10% of heavy duty trucks. Approximately 25% of transport final energy consumption would be supplied by biorefinery diesel, while around 4% would be supplied by traditional biodiesel.
- Energy efficiency may play an important role to decarbonize the energy system. In the industrial sector, an energy intensity reduction of 14% up to 2050, in comparison with 2015 base year, is possible by implementing state-of-the-art technology (boilers, drives, etc.) and increasing electrification. Electrification rate in the industrial sector may increase to 30%, with large potential in Food and Beverage companies. In the residential sector the electrification rate may increase from current 25% to 32%, especially for cooking and water heating applications.
- Research and Development (R&D) and pilot plants must be cross-cutting policies throughout the decarbonisation process.

National circumstances and findings

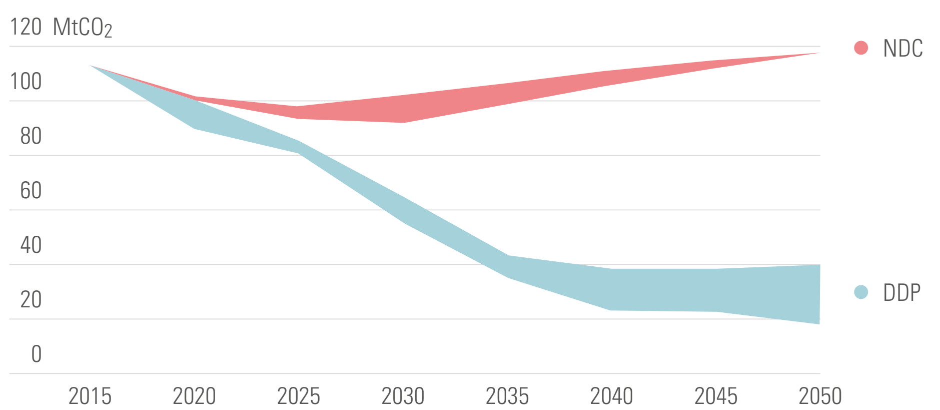
This policy brief presents and discusses the results from the Deep Decarbonisation Pathways in Latin America and the Caribbean (DDPLAC) project for the Republic of Ecuador. This two-year project developed a series of long-term energy and land use scenarios for Ecuador's pathway towards a low-carbon energy and land system by 2050. The project was developed by local and international energy modelling experts and is part of a broader project comprising of six countries in the LAC region: Mexico, Costa Rica, Colombia, Ecuador, Peru and Argentina (IDB and DDPP-LAC, 2019). Climate change (CC) is a global issue that requires action from every country in order to allow for a "well-below" 2°C world (closer to 1.5°C) above pre-industrial levels by the end of this century (IPCC, 2018). In 2016 Ecuador emitted 98.6 $MtCO_2eq$ (CAIT Climate Data Explorer, 2020), and is committing to voluntarily reducing its emissions levels while working to overcome socio-economic development barriers. In March 2019, Ecuador submitted to the United Nations Framework Convention on Climate Change (UNFCCC) its first National Determined Contribution (NDC), both conditional and unconditional to international support, with objectives up to 2025. Later, in August 2019 the Ecuadorian Government declared its NDC to be State policy of mandatory compliance (Gobierno de Ecuador, 2019). This policy brief finds that Ecuador's current NDC is not aligned with a long-term global pathway towards a "well-below" 2°C by 2100, and suggests which measures could be taken for Ecuador towards 2050 to shift its course towards that direction. Further explanation of the methodology used in the study is presented in Annex 1 and in (Villamar et al., 2020).

Ecuador's NDCs are not aligned with a long-term deep decarbonisation trajectory; a long-term integrated strategy (LTS) aligned with Paris Agreement is needed.

Greenhouse Gas (GHG) emissions from energy and land in a scenario aligned with the current Ecuadorian NDC shows a growing tendency that is far from the decarbonisation requirements aligned with a global 1.5°C level by 2100. Ecuador's current NDCs, both unconditional and conditional to international support, are not aimed at long-term deep decarbonisation trajectory. The current NDCs would guide the country towards a slight reduction by 2025, but without further long-term strategies would cause emissions to reach around 120 $MtCO_2eq$/year in 2050. To achieve the Paris agreement, Deep Decarbonisation Pathway (DDP) scenarios shows that GHG emissions would need to be in a range between 20 to 40 $MtCO_2eq$/year[9] in 2050 (**Figure 13**).

9 In the academic publication from Villamar et al., (2020) all the modelling details and scenarios definition are presented. Some DDP scenarios were modelled, using carbon budgets (cumulative emissions up to 2050) for Ecuador between 1.46 and 1.25 $GtCO_2eq$, which are compatible with a global 1.5°C level by 2050. These carbon budgets were estimated with the global COFFEE model (Rochedo et al., 2018).

Figure 13. GHG annual emissions up to 2050 for NDC and DDP scenarios



NDC put Ecuador on a track towards 120 $MtCO_2eq$ by 2050, while DDP scenarios need to be in a range between 20-40 $MtCO_2eq$ by 2050.

To achieve this more ambitious GHG mitigation scenario, Ecuador needs a Long-Term Strategy (LTS) that guides country' transition to more ambitious targets in the energy and Agriculture, Forest and Land Use (AFOLU) sectors as will be explained below.

International cooperation and private investment could help create the enabling conditions for moving in the direction of deep decarbonisation.

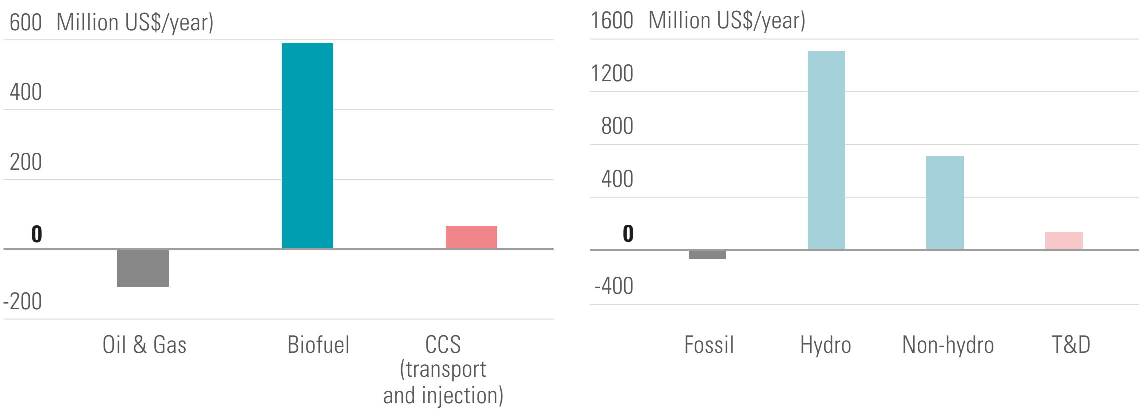
Up to 2050 there would be less investment in Oil & Gas sector and much more in biofuels (590 million USD per year) and transport and injection infrastructure to make CCS possible (65 million USD per year) (See **Figure 14**, left). In the power sector investment in fossil fired power plants would drop, while higher investment would be required for hydro (1,500 million USD per year), non-hydro (715 million USD per year) and transmission and distribution (T&D) (140 million USD per year) (See **Figure 14**, left).

Diversifying the power matrix with non-hydro renewable energy is key to reducing the dependency on large hydropower generation.

Ecuador should diversify its electricity generation system with non-hydro renewable energies to reduce the dependency on large hydropower generation, which could worsen in climate change scenarios with less precipitation (P. Carvajal et al., 2018; P. E. Carvajal, 2019). Up to 2050, our modelling suggests the power sector needs to deploy at least an installed capacity of 4.4 GW solar PV (utility scale and distributed generation), 3 GW of biomass-fired thermal power plants with carbon capture and storage (BECCS), 900 MW of on-shore wind and 500 MW of geothermal plants (See **Figure 15**). This adds 9 GW, which is 17 times more than 2020 non-hydro installed capacity. Hydro power plant would remain as the most important generation source with a total of 8 GW of installed capacity in 2050, including an additional 3 GW from 2020. Electricity generation installed capacity in 2050 would be 18 GW. Although there is still an important remaining techno-environmental hydropower potential in the Amazon region (13 GW), its additional deployment based on run-of-river plants would lead to operational problems in the electricity sector, especially at the time of low hydrology, coincident in the Amazon and Pacific basins, at the end of each year. Storage biomass capacity would allow supplying firm electricity with biomass thermal power plants during this period. Thus, thermal power plants fuelled with biomass is a suitable option for Ecuador, a country with large potential for bioenergy.

Natural gas (local and imported) may be an option to fuel around 600 MW of combined cycle thermal plants to provide firming power to support intermittent renewable energy sources. CCS could be

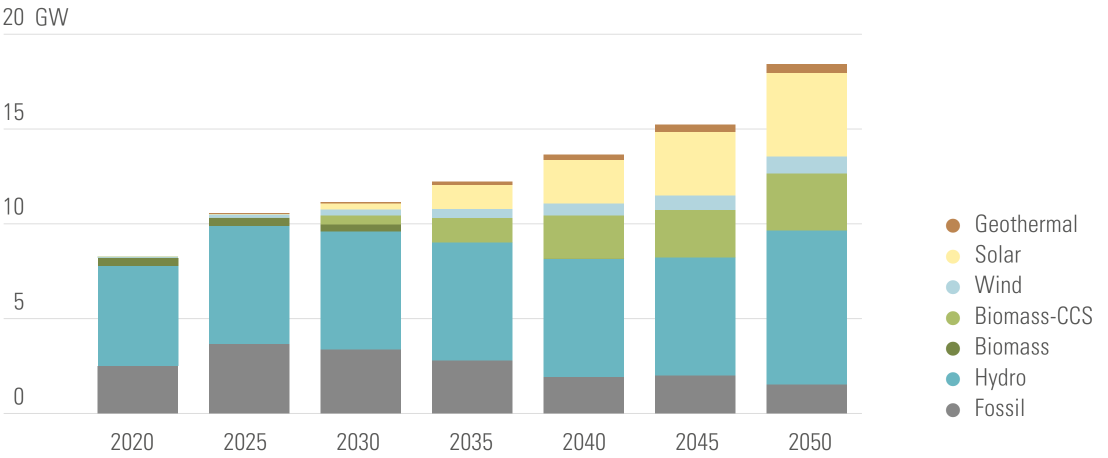
Figure 14. Additional annual investment required for DDP scenario, in comparison to the reference case, 2020-2050



a. shows Oil&Gas, refineries and bio-refineries, and transport and injection for CCS

b. shows power plants and transmission and distribution (T&D)

Figure 15. Evolution of power generation installed capacity in a DDP scenario up to 2050.



partially applied to the remaining fossil fuel thermal power plants. The deployment of the above-mentioned technologies would lead to 94% of renewable electricity generation in 2050.

The expansion of the power sector up to 2025 is aligned with the Ecuadorian Master Electrification Plan (PME 2027), which already proposes 1.1 GW of combined cycle thermal plants with imported liquefied natural gas (LNG); and, non-hydro renewable options (600 MW) including solar PV, on-shore wind and geothermal (MERNNR, 2020). The PME also shows an expansion of 2.4 GW between 2020-2027.

This is a challenge that remains not only for the Strategic Public Company Electric Corporation of Ecuador (CELEC EP) but also for the private sector. In the short and mid-term, the Government should create the appropriate enabling framework to allow private investment participation in the power sector.

The development of the bioenergy industry is key for a deep decarbonisation.

Wood from managed forests, mainly from reforestation programs on degraded land, could be an important fuel for thermal power plants (with or without CCS). Biomass will not only be important for the power sector, but to decarbonize the whole primary energy supply matrix for the whole economy. Biomass could also be used as raw material for the production of advanced liquid fuels and sophisticated chemicals in bio-refineries. An installed capacity growing to approximately 45 thousand barrels of oil equivalent per day in bio-refineries would be required by 2050. Around 25% of freight transport's final energy consumption could be replaced using advanced biofuels in the medium and heavy truck fleet. In addition, to face the imminent exhaustion of Ecuador's petroleum resources, which would happen before 2040 at current production rates, the development of bio-energy crops from 2030 onwards is an alternative key activity to both decarbonize the energy matrix, and to generate income and jobs in rural areas. Ecuadorian oil depletion brings challenges not only for the energy sector, but also consequences in terms of trade deficits. If a bioenergy industry is successfully developed, it would be able to provide around 80 million barrels of oil equivalent in woody products to the energy sector (bio-refineries and thermal power plants) in 2050, which assumes the sustainable management of around 500 thousand hectares of planted forest. This option can help mitigate risk in the energy sector and set Ecuador on a track for sustainable development and socio-economic growth. In 2015 forest area in Ecuador was 12.8 million hectares (51% of the continental territory), of which 27% was protected forest.

These outcomes may help to strengthen and direct the National Bioenergy Strategy (PNUD/MAE, 2018) and the Proposed Plan for a National Biodigester Program (IIGE/MERNNR, 2020) that are being developed by the Ministry of Environment (MAE) and Ministry of Energy (MERNNR), respectively. These policy instruments should foster both thermal power plants fuelled with biomass products (solid, liquid and gas) and biorefineries. Agro-industrial residues, especially from oil palm, rice, sugar cane and banana, also present a significant energy potential that could be used in the short-term for electricity distributed generation.

An ambitious reforestation program can avoid the dependence on immature, risky and expensive carbon capture and storage (CCS) technologies in the energy sector.

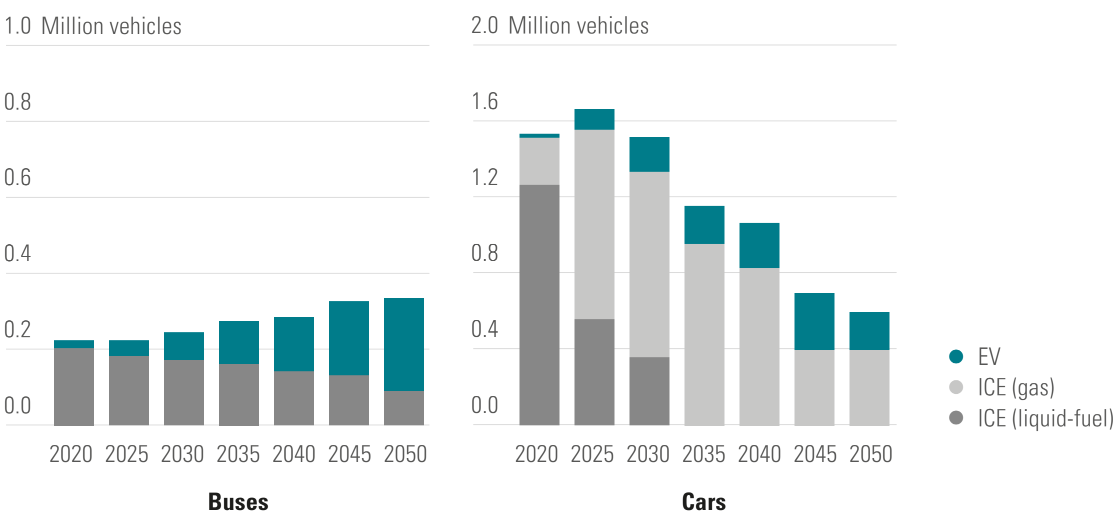
There is a trade-off between bioenergy carbon capture and storage (BECCS) in the energy sector and reforestation/forest conservation in the AFOLU sector. While BECCS is an option to have negative emissions in electricity generation, in the mid-term, BECCS remains as an expensive and risky technology due to its commercial immaturity. On the contrary, reforestation appears as a short-term suitable option for a country like Ecuador, a country rich in fresh water sources and with large biodiversity due to its climate and location. Reforestation (with forest and grassland) and conservation of additional 300 thousand hectares, in comparison to the 2015 base year, would provide enough negative emissions to avoid the deployment of an additional 900 MW of BECCS. In fact, reforestation brings some positive co-benefits related with keeping ecosystem services, additional tourism for example.

The considered reforestation goal is larger than the goal established by both the National Forest Restoration Program (40,000 ha) and by the Ministry of Agriculture forest plantations for commercial use program (120,000 ha). On the other hand, the proposed goal is significantly less ambitious than the 'Socio-Bosque" program (conservation of 3 600,000 ha) (MAE/FAO, 2019).

Electrification of the passenger transportation is essential to reduce emissions in the transport sector.

Deep decarbonisation by 2050 demands an increase of public transport use, as well as an increase in its electrification rate. At national scale, electric buses in 2040 should represent half of the bus fleet and by 2050 over 70% (See **Figure 16** left). Around 20,000 electric buses would be operating in 2050. This important change responds to the Organic Law of Energy Efficiency, issued in 2019, which mandates that "from 2025 all vehicles that join the urban and inter-parish public transport service in continental Ecuador should only be electrically powered" (*Asamblea Nacional de la República de Ecuador, 2019)*. Thanks to the increased use of public transport from 2030, private mobility demand should decrease. Ambitious goals are required from 2030. By 2035 fossil liquid fuels should no longer be part of the private passenger transport energy matrix, except for justified cases. Instead, the private car fleet would be powered by natural gas (local and imported) and electricity (See **Figure 16**, right). Although a significant reduction of electric vehicle prices is ex-

Figure 16. Passenger transport demand for public transport (left), and private transport (right).



pected in international markets leading up to 2050, our modelling finds they remain relatively expensive in comparison with internal combustion engines (ICE), leading to a 2050 car fleet composed one third by electric cars. Electric trains (metro in Quito, tramway in Cuenca) and electric motorcycles will play an important role in a DDP scenario to increase the use of public massive transport systems.

GHG emission reduction in the transport sector does not depend only on electrification; there must be a switch from personal to public mobility, and a reduction of motorized mobility. In 2015 buses supply 56% of passenger motorized transportation demand, cars 33%, motorcycles 3% and airplanes 8%. In a DDP scenario, in 2050, buses would supply 63%, cars 14%, motorcycles 9%, airplanes 10% and trains 3%. Policies should foster non-motorized mobility (walking, biking, skates and skateboards) in cities. Around 10% of total passenger transportation demand could be supplied in a non-motorized way (**Figure 17**). Urban planning and social misconceptions of transport need to be addressed in order to improve urban mobility. Electrification of the public transport system should be associated with improvements in security, travel time, comfort, particulate matter emissions, etc. The private fleet could be electrified, but if complementary policies formulated with a holistic view do not take place, the mobility problem will remain.

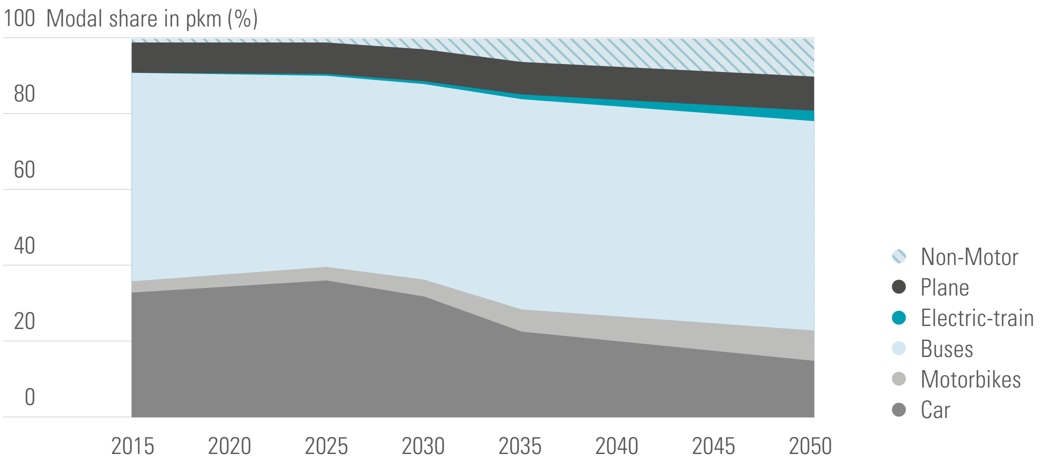
The Strategic Mobility Plan 2013 -2037 developed by the Ministry of Transport and Public Works (MTOP, 2016), which is strongly focused on infrastructure construction (roads, ports and airports), should be updated to set goals in the above mentioned axes too, looking to activity, energy intensity, energy mix and environmental problems (local and global) too.

GHG mitigation in freight transport is challenging, it requires electrification and use of advanced biofuels.

Final energy consumption of freight transport is estimated to be 127 million barrels of oil equivalent in 2050 in our DDP scenario. GHG mitigation in this subsector is the most challenging as these activities require large amounts of energy concentrated in a small volume. Thus, one option to decarbonize freight transport is the use of advanced fuels produced from biomass in bio-refineries. By 2050 approximately 25% of the sector's final energy consumption is estimated to be supplied by biorefinery diesel, while around 4% would be supplied by traditional biodiesel. These biofuels could be used by existing medium and heavy trucks with minor adaptation to their combustion engines. Complementarily, the light and remaining medium truck fleet could be partially electrified. By 2050 only 10% of the heavy truck fleet may be electric, while this value increases to 40% for the medium and light trucks fleet.

Electric trains for freight transport remain as important options in the mid and long-term. In our DDP scenario electric trains could meet 10% of freight transport demand by 2050. The Ecuadorian Government has evaluated electrifying the Quito-Guayaquil train (MTOP,

Figure 17. Evolution of modal share for passenger transport in a deep decarbonisation scenario up to 2050



2016), and the Daule-Guayaquil-Posorja-Manta train (MTOP, 2018) projects, and making these large-scale projects a reality involves significant participation by private capital and international cooperation.

Energy efficiency may play an important role to decarbonize the energy system.

In the industrial sector, an energy intensity reduction of 14% by 2050 in comparison with 2015 base year, is possible by implementing state-of-the-art technology (electric boilers, efficient drives, solar low and mid-temperature heating, etc.) and increasing electrification. The electrification rate in the industrial sector may increase from current its 25% to 29%, especially in Food and Beverage companies. In addition, higher electrification in the residential sector is possible, especially for cooking and water heating. In our DDP scenario the electrification rate in the residential sector increases from its current 25% to 32%. However, this energy efficiency potential is limited by the current levels of energy subsidies (Schaffitzel et al., 2020).

Although the study did not assess industrial cogeneration and solar industrial heating, other studies show their significant contribution to the energy matrix and environment. The installation of industrial cogeneration technologies (600 MW) in 555 companies may decrease at least 30% of diesel consumption in heating applications (CELEC EP/ UCUENCA EP/MERNNR, 2017). In Imbabura, Pichincha and Loja provinces there are several industrial plants with ideal conditions for the application of concentrated solar for heat industrial process, replacing diesel and bunker (Soria et al., 2020). In addition to the presence of fossil fuel subsidies, another barrier for cogeneration is the low electricity tariff for this electricity generation, while for solar heating, research and development funds to nationalize Fresnel concentrating solar technology are required to make cheaper solar heat.

Research and Development (R&D) and pilot plants must be cross-cutting policies throughout the decarbonisation process.

The Academy, as well as national research institutions (IIGE, INIAP, etc.) should be involved in the decarbonisation process. While reducing GHG emissions, economic development and quality of life improvements should also be sought. Thus, in the mid and long-term the country should be able to domestically produce knowledge and to some extent, technology. Some of the disruptive technologies to achieve decarbonisation are highly demanding of theoretical and applied knowledge, which the country should develop in order to avoid falling into technological dependency with developed countries.

Findings show that DDP scenarios are challenging, but do not compromise socio-economic development. Decarbonisation is possible without affecting Gross Domestic Product, population growth, food and energy accessibility. On the contrary, the DDP scenarios were built over premises that considered modern energy services access and sustainability in the land and energy systems. The main challenges for Ecuador are in the transport sector, where electrification of light vehicle fleet will not be enough. Additional efforts to promote mass public electric passenger transport system and replacement of diesel by advanced diesel from biomass in the heavy cargo transportation are required.

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ANNEX 1: METHODOLOGICAL NOTES

The Ecuador Land Use and Energy Network Analysis - ELENA model developed by the *Escuela Politécnica Nacional* (EPN), with the technical assistance of the *Federal University of Rio de Janeiro* from Brazil, during DDPLAC project, is available to assess decarbonisation pathways for Ecuador. ELENA model is used to assess the expansion of the energy system, possible land use changes and evolution of GHG emissions up to 2050. This is an integrated optimization model that considers the whole energy conversion chain, from primary energy to useful energy, for each of the economic sectors. ELENA also models the land use system; it calculates the land use changes according to the food demand and deforestation/reforestation scenarios up to 2050. Useful energy and food demands are exogenously calculated, as well as deforestation/reforestation scenarios.

A set of scenarios describing demands perspectives and the evolution of technological parameters up to 2050 were used to determine different energy and land use pathways for the coming decades.

A total of six scenarios were analysed. First, a scenario that describes the business-as-usual tendency (Reference case based on least cost decision). Two scenarios model Ecuador´s National Determined Contributions unconditional and conditional, achieving specific goals in 2025. Finally, three scenarios modelling Deep Decarbonisation Pathways (DDP) are used. DDP_{High} scenario includes a maximum value of cumulative emissions until 2050 of 1.46 $GtCO_2$eq. A stricter constraint was considered in DDP_{Low} scenario, allowing only 1.25 $GtCO_2$ eq. These emissions limits were calculated with the support of COFFEE global model (Rochedo et al., 2018). Finally, the DDP_{High_Refo} scenario has the 1.46 $GtCO_2$eq limit, but includes a mandatory reforestation policy. The use of these GHG emissions restrictions ensures that by 2050 considered DDP scenarios are compatible with a global 1.5°C level.

A complete description of ELENA model, its data base and the modelled scenarios are available in the academic publication of (Villamar et al., 2020).

MEXICO
STEERING TOWARDS PARIS: POLICY INSIGHTS FROM A WHOLE-ECONOMY DECARBONIZATION PATHWAY ANALYSIS

Authors: Jordi Tovilla and Daniel Buira of Tempus Analytica, Ltd.

Key policy messages

- Implementation of Mexico's current climate and energy policies, including the NDC of 2015 and Mid-Century Strategy published in accordance with Article 4.19 of the Paris Agreement, will be contrary to the achievement of the Paris Agreement goals.
- Whole-economy decarbonization planning tools can provide practical insights on how to shift Mexico's sectoral and development pathway towards Paris.
- Major energy sector restructuring is urgently required to achieve a rapid wholesale substitution of oil and gas by renewable electricity as the main source of primary energy across all sectors including transportation, buildings, agriculture, as well as much of industry.
- Rapid uptake of measures to change both urban dynamics and transport fleet technologies can radically curb the demand for private vehicle use and energy, with clean electricity further reducing emissions of today's fastest-growing sector.
- The potential for forestland to contribute the significant negative emissions required to achieve net-zero by 2050 not only calls for rigorous ecosystem stewardship, but also for deep technification of agricultural practice across livestock and crop management to reduce ongoing agricultural emissions.
- These profound structural transformations can only come about within a re-casting of Mexico´s social and economic development pathway to 2050 and beyond, which has clear policy and investment implications for the short and medium term.

Introduction: Mexico's current plans will not achieve the Paris Agreement

The Paris Agreement, adopted in December of 2015, is seen as a watershed in international climate negotiations. Although the goals stated in Article 2 align with the science of minimizing the adverse effects of climate change, the actions taken by countries to achieve them are nationally determined. Success or failure will therefore depend on the aggregate effects of disparate national policies, as opposed to the mechanics of the Agreement itself.

In 2018, the Intergovernmental Panel on Climate Change – charged with identifying the best available science to inform policy – published its Special Report on Global Warming of 1.5°C. In this, the IPCC states categorically that the Nationally Determined Contributions communicated by countries until that date are not only insufficient to achieve the Paris goals, but are in fact contrary to the Agreement. If countries implement their NDCs as they stand, they will lock in so many emissions as to make the Paris goals impossible to achieve (de Coninck, y otros, 2018). The IPCC advises countries to develop transformation pathways to 2050 with a view to reducing global emissions by half in 2030 and achieve net-zero emissions in 2050. Mexico's climate change plans and latest energy policy, as highlighted in its NDC (Government of Mexico, 2015), Mid-Century Strategy (SEMARNAT-INECC, Mexico's Climate Change Mid-Century Strategy, 2016), and Energy Transition Strategy (SENER, 2020), aim to reduce emissions intensity per GDP but map out a road towards 2050 which may result in greater absolute emissions than today. Sadly, this problem is not unique to Mexico, but a result of the planning paradigm within which national policy has been developed. Although the IPCC is clear that deep structural change is required, most countries have generated policy in the usual manner, identifying incremental improvements which are inadequate, thereby committing to unacceptably high future emissions. For Mexico, this could result in failure to achieve its national climate commitments, while further betting economic prosperity and financial stability on a fossil fuel economy which must drastically decline by the middle of the century.

Methodology: Decarbonization tools can map out pathways towards net-zero emissions

This project uses the Deep Decarbonization Pathways method (Waisman, 2019) which sets out a process for designing country-driven visions of transformation to achieve climate goals and sustainable development. Core methodology elements include setting an ambitious target for 2050 (net-zero or well on the way to net-zero in a manner compatible with the Paris goals), "backcasting" from the target to the present, a "whole-economy" focus so all (or as many as possible) sectors and GHGs are considered, and a "dashboard" tool to allow meaningful integration of results generated in different ways to create a holistic picture. The method highlights trade-offs and synergies while recognizing the inextricable relationship between social and economic development and emissions goals. Detailed physical transformation pathways are then created for each sector, identifying short, medium and long-term actions and policies to ensure these transformations can happen.

Projecting pathways into the long-term future allows us to outline a transition towards zero-carbon while considering the natural life cycle and turnover of equipment and infrastructure, modifications in behaviors of people, and aspirational socioeconomic goals. In addition, it identifies and avoids solutions that may offer apparent short-term benefits but are obstructive in a longer timeframe – e.g. by leading to locked-in emissions or stranded assets – thereby directly addressing the challenge faced by most country NDCs today. This feature is crucial when planning

capital intensive infrastructure, and also when making decisions that determine future market dynamics.
Planning the decarbonization process should be guided by conceptual pillars which must all be pursued at the same time:

- Rapid decarbonization of electricity systems through rollout of renewable energy and clean firm power to support it.
- Widespread electrification of energy use, driving the uptake of low-carbon energy.
- For energy uses not easily electrified, switching to alternative zero-carbon fuels.
- Widespread pursuit of efficiencies in products and processes to improve energy intensity across all sectors (e.g. transportation, industry, agriculture etc).
- Improving urban structure to reduce people's footprint and improve their quality of life.
- Boosting natural carbon sinks through good management of forests and other ecosystems.
- Transforming agriculture to reduce emissions from crops and livestock and increase carbon sinks.

We projected two scenarios of Mexico's economic development to 2050 based on the same economic and population growth. The first assumes NDCs will be implemented to 2030 and similar ambition extended continued to 2050, providing a Reference Scenario (REF). The second or DDP Scenario was developed explicitly to achieve the Paris goals using the conceptual pillars highlighted above. Modelling both pathways across seven sectors while tracking emissions of three greenhouse gasses allows direct comparisons to be made, thus highlighting the key differences which must be addressed if Mexico is to correct its course.
We employed a multi-tiered approach to pathway analysis. For electricity and transportation, detailed modelling was carried out using **Energy PATHWAYS** (Evolved Energy Research, 2019). This bottom-up energy accounting tool models the energy economy with detailed granularity and allows a backcasting approach to demonstrate what physical infrastructure changes are required to reach set goals. The evolution of electricity generation technologies (and their coupling of other energy sectors) were modeled with **RIO,** the Regional Investment and Operations platform (Evolved Energy Research, 2019). This optimizes the cost of expansion of capacity for electricity generation, fuel production, and the transmission infrastructure required, with detailed sequential hourly system operations, enabling the analysis of the energy system as a whole.
The transformation of all other energy sectors is described at the "dashboard" level, specifically by modification of Kaya identity drivers (activity, energy and carbon intensities) in each sector. Non-combustion emissions from industrial processes are also tracked at dashboard level. Non-energy sectors and emissions (AFOLU, Waste) have been included at a preliminary dashboard level, as the tool used is still under development.

Results: Sectoral decarbonization can underpin economic and social development pathways

Our work resulted in sectoral narratives of change with clear differences from current Government of Mexico (GoM) plans.

Electrification will transform all energy sectors. This will significantly increase demand for electricity – mirrored by a correspondingly rapid fall in fossil energy demand – which in turn must be provided by zero-carbon technologies. Our detailed technical analysis gives confidence that an accelerated, large-scale rollout of decarbonized power generation will provide reliable, competitive zero-carbon energy for other sectors to use in their own rapid transitions. Concretely, **Figure 30** shows the difference in power generation and storage rollout by technology in the two scenarios, with an example of the resulting DDP hourly power dispatch in 2050 (seen in 31) demonstrating the viability of this very high renewable approach.

Passenger transportation is currently the sector with largest and fastest-growing emissions. Further growth is expected as the population becomes wealthier, aggravated by uncontrolled urban expansion. Hence, a core narrative element of this work is that urban development should happen in a different way, not only to reduce emissions growth, but to increase public health and wellbeing. Changing urban structure will distribute services and opportunities more fairly within the citizenry, while building a robust public transport system to improve passenger comfort, safety, and travel times. At the same time, rapid rollout of decarbonized trams, busses and cars will be required (**Figure 32**), powered by renewable electricity instead of fossil fuels. This will significantly increase overall demand for electrical power while reducing demand for oil.

Oil and gas demand reduction (**Figure 33**) is a necessary part of deep decarbonization: as personal mobility in Mexico decouples from fossil fuels, export opportunities will also diminish since other countries will undertake similar decarbonization measures. This is in stark contrast with stated GoM policy to invest in increased oil production and refining capacity. Mexico's demand for fossil gas, currently from both power

Figure 30. Installed electric capacity (GW)

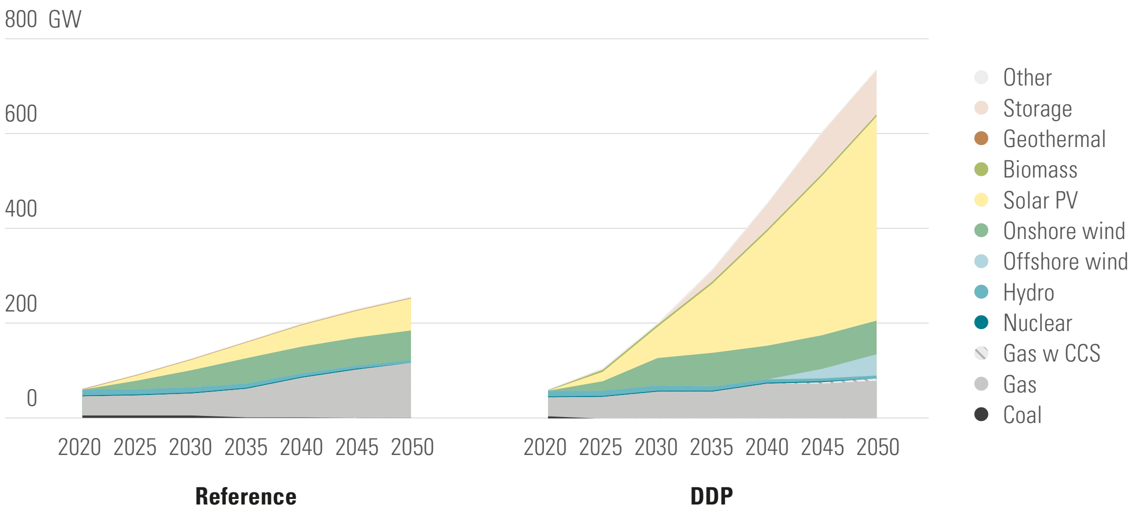


Figure 31. DDP hourly electricity dispatch in 2050 by region (GW)

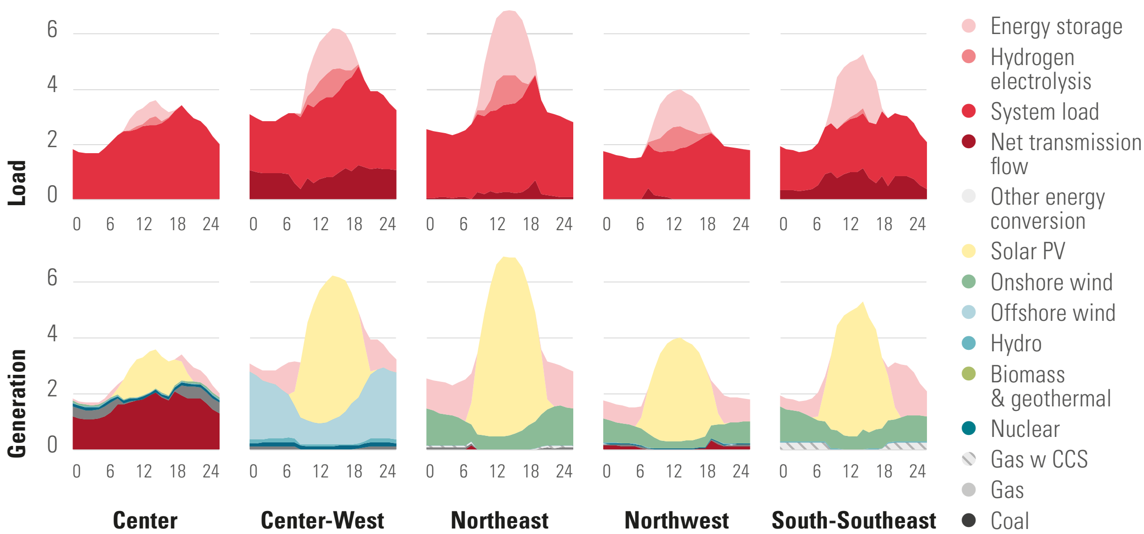


Figure 32. LDV transition to EVs

Top: sales (%); Middle: annual service provided (billion vehicle-km); Bottom: energy demand (EJ)

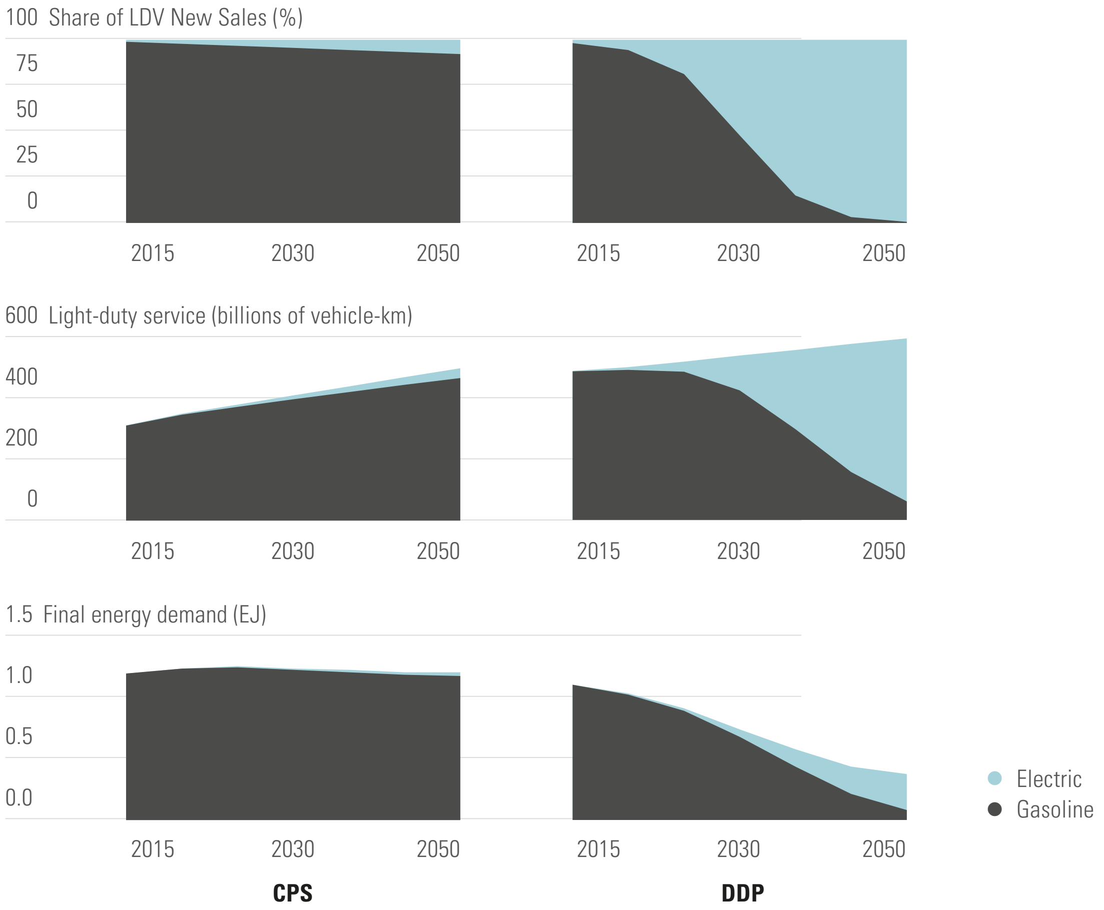
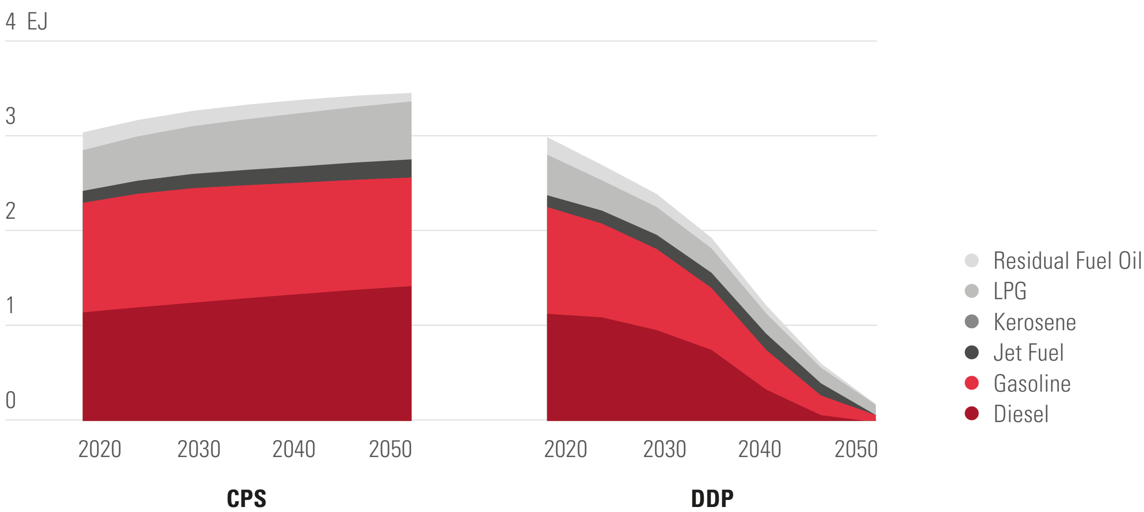


Figure 33. Demand for petroleum-derived fuels (EJ)



generation and thermal use by industry and buildings, will phase out more slowly. However, this fuel is largely imported from US low-cost shale production, making its substitution by renewables a driver of greater national economic activity and energy sovereignty.

Freight transportation and industry will see both efficiency improvements and direct electrification proceed rapidly where practical, while step-change modal shifts in some high-demand corridors of freight transport, and process innovation for industry, will further reduce emissions. Significant energy needs will remain, however, for which over time, additional zero-carbon fuels will be generated through a range of technological pathways, powered either by biomass, waste, or renewable energy. These will gradually phase out fossil fuels, with the substitution well underway – but not completed – by 2050. The industrial transformation to deliver zero-carbon fuels presents additional opportunities for post-oil investment and economic activity.

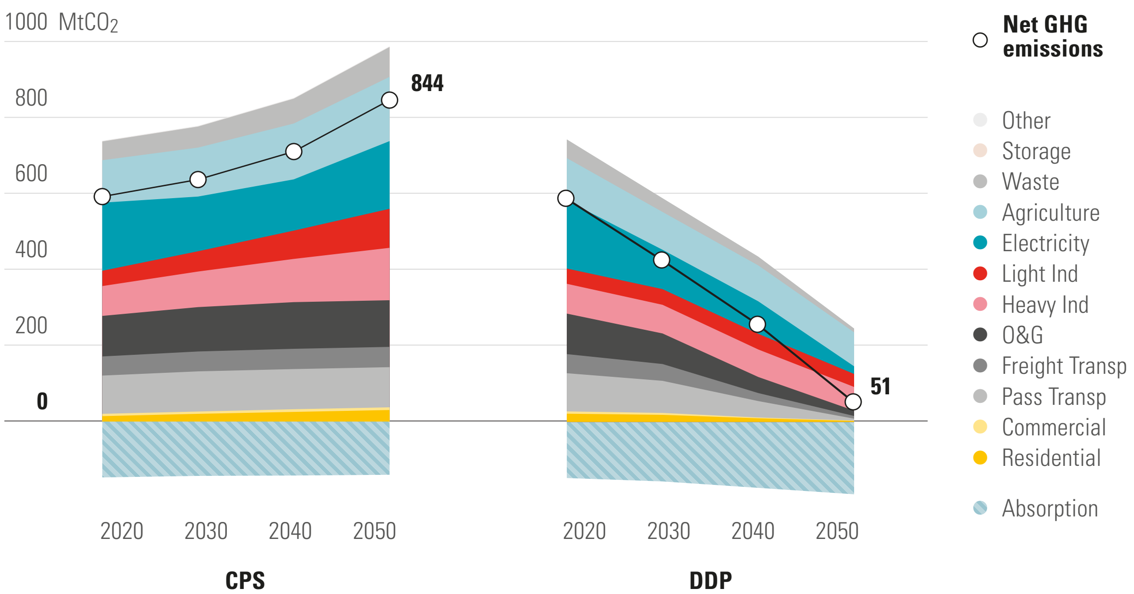
Buildings emissions, which gradually grow in the current policy scenario as increasing prosperity outpaces continuous efficiency improvements, can be rapidly reduced through a combination of solar heating (which is a widespread solution across similar latitudes along the world) and electrification, coupled with upgraded standards for construction, equipment, and appliances.

Distributed power generation presents another important economic opportunity, particularly in the residential sector for which electricity used – largely generated from fossil fuels – is currently subsidized. Investment in distributed solar PV technology can simultaneously cut emissions and reduce government costs.

AFOLU is crucial as Mexico must increase GHG absorptions from this sector to meet its targets. Improved forestland management will be combined with intensification of farm productivity (which releases land for afforestation) to grow the sink. This will be complemented by gradual reductions in emissions from fertilizer use as well as enteric fermentation and manure management, largely decoupling agriculture growth from emissions growth. While our analysis does not detail the AFOLU transformation, it highlights the requirement for deep technification of the sector from a whole-economy perspective, emphasizing emissions drivers of historic importance which policy should focus on.

The net result of these sectoral transformations can be seen in **Figure 34**. While current policy is estimated to lead to net 2050 emissions of 844 $MtCO_2$, net DDP emissions become 51 $MtCO_2e$, 94% lower. Per capita emissions will have fallen from 4.2tCO_2e in 2015 to 0.3tCO_2e in 2050, in line with a global temperature rise of between 1.5 and 2°C. The most dramatic reductions will come from changes in energy use, with

Figure 34. GHG emissions pathways by sector, including absorptions, for REF and DDP scenarios (MtCO2e)



a resulting sharp decline in oil and gas activity. Forests slightly increase CO_2 absorptions from present values, while food systems' GHG footprint is stabilized and gradually managed down. Since our analysis of agriculture and industry is less detailed than for other sectors, further work may reveal additional opportunities for emissions reductions.

Conclusion: Rapid and profound policy shifts are needed if Mexico is to succeed

Mexico can achieve the Paris Agreement goals while improving the life of its citizens. However, this will require a shift away from the current development pathway and the narrative that has been central to the public policy debate for the past generation. A different planning paradigm and a significant redirection of investment will be needed to implement this new development vision. Mexico's renewable endowments, industrial base, geographical location, and skilled workforce make this transformation – which must occur at a global scale – an opportunity to advance towards a high-tech knowledge-based economy, catalyzing economic growth, increased prosperity, and greater inclusion.

Single policy measures will not be sufficient. Suites of complementary policies, or "policy packages" across different sectors will be required to work together, and they will be most effective combining cross-cutting policies with sector-specific measures. Below we present a number of cross-cutting policy changes which will be needed to enable sectoral change:

- **Planning:** The federal government should formulate as soon as possible and in collaboration with stakeholders from productive and social sectors, an integrated long term plan for decarbonization by 2050 which sets ambitious long-term targets and clear milestones along the way. From this, the sequence of necessary changes must be identified, as well as concrete policy actions to achieve them. In this manner, the urgent short-term actions required to reach a long-term transformation can be undertaken quickly from 2020. This strategy should update the existing Mid-Century Strategy (MCS) and feed into the NDC update process.
- **Labor:** A just transition should be a cornerstone of the transformation if it is to succeed while driving social and economic development. Ensuring this will require clear institutional arrangements with roles and responsibilities. The federal government should consider the establishment of a multi-stakeholder council or similar body to provide broad direction and oversight to just transition activities, while leading voices from within growth sectors should identify and communicate the scope for growth and creation of new jobs. Worker representatives and unions, particularly from sectors set to decline, should collaborate with growth sectors to identify the training and other support that will be needed for those individuals seeking to change sectors. Joint investment from central government, local communities and the private sector, together with international collaboration, should be sought to support this transition, which can simultaneously achieve additional social and economic objectives. For example, the sustained investment and training involved can provide means to ensure more Mexicans join the formal economy, increasing their productivity, social protection, and fiscal contributions.
- **Regulatory standards:** Carbon intensity and performance of products and behaviors should form key criteria of regulatory approval across all sectors, ranging from building codes, industrial equipment, vehicles, home appliances and consumer products, as well as guidelines for public procurement and spend. Agreed phase-ins of standards over time, following a calendar of increasing stringency, must be established early on across sectors to give clear signals to the marketplace, with key market players collaborating with the relevant authorities through organized schemes which ensure transparency in terms of alignment with the Paris goals. This will naturally feed through to prices, resale values, and product launches, modifications, and market withdrawal of products and services which are not compliant.

- **Public prices:** Ministries of finance around the world will have to play a decisive role for the low carbon transition to take hold, and for Mexico this will be no different. Taxes, tariffs, incentives and subsidies should evolve to increase the cost of those activities which must rapidly reduce in volume, while supporting the uptake of new technologies and practices. The timing of these measures could be gradual or tiered to facilitate market acceptance, however support for new alternatives options should ramp up at the same time (or preferably before) high-carbon alternatives increase in cost to accelerate change while avoiding hardship.
- **Fiscal sustainability:** The ambitious economic and social development program required to achieve national goals calls for the state to provide vision and leadership while fostering education and investment. Managing this change will need strengthened skills and systems within the public administration at all levels of government. Within this context, Mexico's historical dependence on oil revenue for fiscal stability – which is not representative of the diverse, service-led economy – will become rapidly inadequate as oil activity declines globally to avoid the catastrophic effects of climate change. Mexico must therefore set out a new vision of fiscal sustainability. A stronger link between fiscal take and national economic activity will lead to a virtuous circle as investment in the transition stimulates activity which in turn leads to increased intake, enabling further investment. As new opportunities generate jobs, it will become easier for citizens to join the formal economy. The trajectory of the tax burden over time must align with national and local goals and the overall technology pathways. Furthermore, most resources for states and municipalities currently trickle down from federal sources, meaning local revenues and tax systems will need to be strengthened to fund long-term ambitious projects suitable to local needs.

Sector-specific policy changes are also needed, including:

- **Cities:** The role of the urban structure as a driver of citizen quality of life must be given a central place in national planning, particularly for efforts seeking to improve equity. A holistic view including job opportunities, access to services, public health, quality of building stock and availability of quality transportation (including safety, reliability, comfort, and journey times) should drive planning efforts, regulation, and investment.
- **Transportation technology:** Achieving modern public transport networks which serve a far higher percentage of the population must be a core pillar of the Mexico's urban development. Within this, the urban transport fleet – both public and private – must be electrified rapidly, effectively increasing EV sales from 2020 to overtake ICE sales before 2035.
- **Energy:** Future national prosperity and sovereignty must become rooted in Mexico's abundant renewable resources which, capitalizing on the country's manufacturing and work-force strengths, should become the main recipient of energy investment. Rapid roll-out of renewable generation capacity will be needed to satisfy increasing demand while also replacing current fossil generation. Therefore, investment focus must turn away from the oil and gas sector, which bets future prosperity on uncertain international commodity prices while compromising public health and making climate goals impossible to achieve.
- **Industry:** The opportunities created by the renewable electricity surge and electrification of transport should guide the direction of future industry growth, even while reducing dependence on fossil fuels and re-tooling where appropriate for zero-carbon fuels from renewable sources (waste, bio, synthetic from zero-carbon electricity). As other countries also pursue decarbonization, the loss of income from oil exports should be replaced by increased activity in low-carbon technologies such as clean energy, EVs, and sustainable building materials.
- **AFOLU:** Stewardship of forestlands should continue to improve, seeking to maintain or increase the current carbon sink for decades to come. However, this will only benefit the national transition if farming emissions are simultaneously reduced by changing practices in both crops and livestock, as well changes in customer demand. Should farm emissions growth follow recent trends, these increased emissions will cancel out any absorptions from forestry to 2050, suggesting the need for policy action which links agricultural prosperity with good forest management.

PERU

GETTING TO NET-ZERO EMISSIONS AND CREATING FURTHER OPPORTUNITIES IS POSSIBLE: THE CASE OF THE AFOLU AND TRANSPORTATION SECTORS

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Key policy messages

- Peru is highly vulnerable to climate change, and its two key contributions are likely to be in minimizing its agriculture, forestry, land use (AFOLU) and personal transport emissions as it develops.
- Peru's current NDC policy actions on AFOLU are pointing in the right direction but need to be considerably strengthened. i.e. 1) Sustainable Management of forest concessions; 2) Improve forest management in native communities; 3) Incentives to native communities for forest conservation; 4) Improve management in Protected Natural Areas; 5) Allocation of rights of use in areas in which they do not exist; 6) Addition of commercial forest plantations.
- There is trade-off between reduced deforestation, afforestation and food production that must be anticipated and planned for.
- Peru needs to form a national plan and implementation policy package for transport, including land use for more transit and mode shifting with a focus on urban and inter-city electric buses, and more general electrification of vehicles. More policy work is warranted.
- The estimated DDP pathway results show a 75% reduction from AFOLU, and an 80% from BAU transport emissions, -50% from today, with reduced congestion and local air quality benefits

A path to net-zero emission is possible for Peru

The Paris Agreement has established a compromise between countries to mitigate the greenhouse gases (GHG) emissions in all socio-economic activities. Through voluntary National Determined Contributions (NDCs) each country adopts measures for progressive decarbonization to hold global warming below 2°C above pre-industrial levels.

In Peru, the decarbonization of AFOLU[10] and passenger transport sectors are essential as GHG emissions will increase by 1.5% and 4% respectively each year if no action is taken. The modelling of decarbonization on AFOLU policies shows that reducing emissions by 116.6 Mt CO_2 eq. in 2050 compared to Business as Usual scenario, a reduction of 71.4% and an additional 4.06 million hectares of primary forest are preserved, and that this reduction occurs primarily through a decrease of the rainforest deforestation, sustainable forest management, property rights allocation and sustainable management of forest concessions. In addition, the modelling of decarbonization policies in the passenger transport sector shows a reduction of emissions by 25.8 Mt CO_2 eq. in 2050 compared to Business as Usual scenario, a reduction of 85.6%. This reduction occurs primarily through an increase in public transport infrastructure and an electrification of transportation. Passenger transport emissions are reduced, even though the total kilometres travelled increases through time. Overall, the analysis suggests Peru would be on the path to the net-zero emission by 2050.

The forest represents an opportunity for growth and economic development. There are 73 million hectares of forest in Peru, the ninth-largest forest area in the world, representing priceless biodiversity. However, 144,000 hectares are deforested every year. Still, the forest sector and the timber industry contribute less than 0.5% of GDP and one out of three people in the rainforest region is poor. Profound changes are needed to create opportunities for the communities and to conserve the rainforest. Obtaining sustainable value from the rainforest would be an excellent opportunity to show how a deep decarbonization path could provide new income opportunities and preserve the primary forest.

Peru has committed to reduce up to 30% of GHG emissions by 2030. The Nationally Determined Contributions (NDC) involves actions in all sectors and by all actors of society. It is a grand first-step in addressing climate change (and it is a reference baseline). Still, it may not be enough, so it needs to build a reliable road leading to the decarbonization of the economy by 2050.

Efforts are needed in AFOLU to deeply reduced emissions. AFOLU is the highest emitting sector, and it is responsible for 44.9% of total GHG emissions. Rainforest deforestation is the principal source of GHG emissions in AFOLU (81.9%), so efforts must be focused on reduction of the deforestation drivers. Agricultural and livestock expansion is responsible for 76.5% of the annual deforestation.

Producers are increasing their cultivated area by preying on the rainforest. Among small scale and mostly migratory agricultural producers, forest burning is the preferred and cost-efficient practice to deal with the loss of nutrients in the Amazon forest soils. Unfortunately, this practice drives the conversion of primary forest into areas of cultivation. It is estimated that to get one hectare of cropland, farmers removed and burnt 4 hectares of primary forest. The lack of financial and technical capabilities of smallholder farmers results in practices that create erosion and reduce land management efficiency.

Generating value from the forest is the key pathway for decarbonizing the AFOLU sector. To reduce deforestation and enhance forest sinks, efforts need to be made to induce stakeholders to value the sustainable use and conservation of an ecosystem that took centuries to develop. Stopping deforestation by adding value to the long-term use of the forest and the ecosystem services it provides is the main purpose. For a community that is facing development challenges such as poverty, poor health, lack of education and

10 AFOLU sector includes Agriculture and LULUCF (Land use, land-use change, and forestry)

food security, etc., it is challenging to prioritize the long-term value of the forest so creating a short- and long-term value to the standing forest is highlighted as the pathway to stop forest loss.

Deep decarbonization of AFOLU could be achieved with 5 group of actions. To meet the Paris Agreement, rainforest can be decarbonized through: (i) allocation of property rights on non-categorized forest in the Amazon; (ii) increase of sustainable management in forest concessions; (iii) promote of good practices for forest management and conservation in Native Communities; (iv) increase of commercial, protection and restoration forest plantations and (v) improve Natural Reserves management.

Property rights allocation on non-categorized forest in the Amazon is assigning some type of right or entitlement over currently uncategorized forest areas. This is really important because the deforestation rate is led by forests without rights allocation, 36.1% of the annual deforestation, the goal by 2050 is to allocate property rights to 15.3 million hectares. The financial requirement for rights allocation (including titling, monitoring, control and incentive fund) is $536 million dollars (a net present value of $328 million with a discount rate of 10%).

Increase of sustainable management in forest concessions. Sustainable forest management in forest concessions allows forest harvesting activity while not affecting the capacity of the concessioned forests to continue providing their ecosystem functions. The goal by 2050 is to reach 7.4 million hectares of new sustainably managed forest concessions. According to the data of SERFOR, the accumulated financial requirement of sustainable forest management reach $4 billion (a net present value of $2.7 billion with a discount rate of 10%) in 2050. This calculation includes timber transformation in sawn wood and logistics. However, public investment in roads is required because transportation represents more the 60% of the total costs.

Commercial incentives for afforestation and restoration of forest plantations. These are required to induce recovery of deforested land, and as a consequence promote the restoration of forest ecosystems; the goal by 2050 is to reach 2.4 million new hectares of forest plantations. The lack of adequate financial mechanisms and infrastructure gap to overcome the region´s geography are the biggest obstacles for investors. We estimate accumulated investment of $27 billion (a net present value of $3.4 billion with a discount rate of 10%) for 2.4 million hectares of commercial reforestation. These costs include the best technology available in Peru and do not include logistics, timber transformation and additional Government expenses to improve roads. The financial requirement is great for commercial reforestation, but it is the most accepted intervention if we consider that recent studies indicate the sustainable management of primary forests may have important negative impacts in local ecosystems, like nutrient losses from old trees. In addition, recent research indicates that the Amazon rainforest faces a tipping point. In this context, some experts started to recommend aggressive reforestation campaigns and economic activities with the standing forest.

Forest management and conservation by native communities. Paradoxically, most deforestation in the most environmentally rich areas occurs near native communities that have the most to lose from lost traditional agroforestry, but they lack the physical and legal capability to stop it. These communities also tend to be very poor and lack basic services. Forest conservation agreements, along with enforced use property rights associated with use, have been shown to have a positive impact on the standard of life of native communities and reduce the rate of forest loss on native community lands. These agreements, to be effective however, require education and logistics support to encourage the evolution of a combination of businesses based on: sustainable forestry, furniture, sustainable tourism, biotechnology, pharmacy, and high value foods (nuts, etc.). There are also opportunities for biodiversity research and payment for ecosystem services. The goal in our DDP is to reach 11 million hectares managed by native communities. Incentive payments for native communities will require an accumulated sum of $1.5 billion (a net present value of $355 million with a discount rate of 10%) for an accumulated land of 3.8 million hectares by 2050. The challenge is that this intervention is funded 100% by the public budget. It is difficult to foresee the Peruvian Government increasing this budget for this intervention, especially if we consider that the net present value represents half of the Ministry of Environment's current budget.

Isolated interventions have less effect on the GHG emission reduction. Though 2050 each of the above mentioned interventions have the potential to reduce emissions significantly: allocation of rights reduces 620 Mt CO_2 eq., forest concessions 290 Mt CO_2 eq., forest plantations 423 Mt CO_2 eq., improved management by native communities 347 Mt CO_2 eq. and natural reserves management 857 t CO_2. Rights allocation and sustainable forest management synergistically augment their effects if they are applied together. For example, if more lands are allocated under sustainable forest management with better techniques to improve productivity, the forestry profitability will disincentivize the expansion of croplands in forestland. Just reclassifying land is not enough without efficiency and good management, and good management has a limited impact if there are no more available lands. The synergies permit an additional emission reduction of 6.5 Mt CO_2 eq. (not including the isolated effect of policies). In this context, property rights allocation and Forest Management and Conservation in Native Communities provide an accumulated reduction of 35 Mt CO_2 eq., property rights allocation and Natural Reserves management reach a reduction of 55 Mt CO_2 eq. Finally, all the synergy interventions together provide an additional cumulative reduction of 5.6 Mt CO_2 eq.

The integrated analysis of AFOLU (LULUCF and agriculture) allows us to assess their production and food security impacts on the agricultural sector and address the possible unintended effects of LULUCF interventions. The reduction in the conversion of primary forest to cropland implies a drop in the area harvested for crops. Rice, tubers, legumes, fruits and yellow corn are highly dependent on the cropland available in the rain forest. In the year 2050 there 268,000 harvested hectares less than in the BAU scenario. This includes a loss of 124,000 hectares of rice, 44,000 of tubers, 8,000 legumes, and 2,000 fruits. Yellow corn, a Peruvian staple, drops 90,000 hectares. While an increase in imports is not necessarily negative, the political consequences of importing about half of the local consumption of rice may not be acceptable to authorities and the population. On the other hand, for the case of the non-tradable products like tubers, legumes, and fruits the reduction in harvested land would triggers an increase in prices. Given that legumes and tubers are produced by smallholder farmers, mostly in the highlands, the price increase becomes a positive impact on their income as it also drives a higher level of output.

It is necessary to recognize that agriculture cannot continue to grow at the expense of forests. Both the necessary technical improvements and institutional framework for environmental monitoring and the intensification of agriculture must be sought and strengthened. To start addressing these challenges, we present two additional interventions. First, the introduction of a system of rice intensification (SRI) in the coast. The SRI system offers advantages for the farmer and the environment. The yield per hectare of SRI is higher (12%) than the traditional method and has a lower water consumption and generates fewer emissions (-10%). Previous analyses indicate the adoption of the SRI technology requires financing resources and extension support for farmers, and an adequate supply of labor, particularly when smallholders are predominant. The second intervention is a drive to change consumer preferences from rice to tubers and legumes; a natural shift to substitute carbohydrates from rice towards tubers and legumes is a promising long-term trend. Introducing SRI technology and promoting tubers and legumes over rice helps mitigate the reduction of cropland in the rain forest. Price trends for tubers and legumes favor smallholder farmers, the overall quality of the diet improves as tubers and legumes provide additional nutrients to rice, and domestic demand is sourced locally. In summary these interventions allows a reduction in agricultural emissions of 1.7 Mt CO_2 eq. compared to BAU.

Future research agenda on AFOLU. Given the importance of reforestation and the diversity and heterogeneity of the Amazon rainforest, it is important to have a finer assessment of the areas with potential for commercial plantations. Based on existing GIS data is it possible to locate the extensions of land with potential for reforestation, based on access to markets and availability of labor. The microclimate and soil

Figure 35. LULUCF emissions

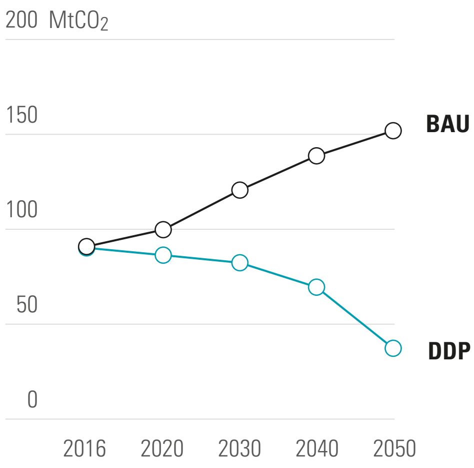
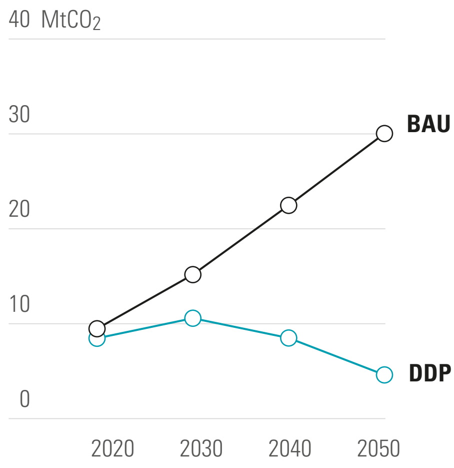


Figure 36. Passenger tranport emissions



characteristics are also to be considered to identify the potential species for reforestation. This detailed analysis is a must to actually confirm the potential that commercial reforestation and sustainable managed of forestry concessions have to contribute to the DDP towards zero emissions.

The decarbonization of the transport sector is key and brings co-benefits. The latest GHG inventory highlights that the energy sector accounted for 25% of the country's gross emissions (4.46 Mt CO_2 eq), with transport representing 40% of the total. This represents the second sector with the highest emissions report. Also, considering that the passenger transport sector has a high growth rate in emissions within the energy sector, it is imperative to structurally prepare its deep decarbonization. At the same time, these structural transformations could contribute to improving the quality of life by increasing access to new opportunities, enhancing mobility by reducing travel time and distance, reducing local air pollution, reducing traffic jams, and increasing labour productivity.

Transport sector has many decarbonization challenges. Total travelled kilometres will grow in line with the population and household income growth; if transport fuel remains fossil fuel based, sectoral emissions will grow. Furthermore, the gap between adequate public transport infrastructures and services contributes to the adoption of private cars and associated traffic jams. According to national surveys, there is a preference for private cars rather than public transport due to feelings of insecurity. In addition, the lack of public refuelling stations for alternative fuels limits the penetration of new technologies of vehicles, especially electric vehicles. Finally, the presence of informal collective transport services by microbuses, collective taxis and two wheelers taxis increases the traffic congestion and has a lower energy efficiency due to the average age of the vehicles. So, there is a clear need to migrate towards a transportation system based on cleaner energy such as electric power or net-zero gases, as well as changes from private towards public transportation and enable people to avoid unnecessary kilometres.

Decarbonization of the sector will be achieved with 4 groups of actions. To accomplish the Paris Agreement, Peru passenger transport sector can be decarbonized with: (i) an increase of adequate public transport services; (ii) a mass electrification of vehicles; (iii) a cleaner supply of fossil fuels and electricity; (iv) and a change of the behaviour of transport sector development.

Peru has already taken some steps. The introduction of urban train and bus rapid transit (BRT) services has reduced the public transport infrastructure gap. While the increase of compressed natural gas stations shifts has allowed the demand of new vehicles with cleaner transportation. At 2020, pilot programmes of electric vehicles and scrapping bonus has started in Lima, which reduce the informality and increase fuel efficiency.

Improvement of quality in public transport services. An ambitious goal could be that at least 50% of the modal shift participation is done by public transportation since 2030. Many infrastructure investments are needed. BRT (Bus Rapid Transit) could be developed more rapidly. For example, 12 news BRT systems could be introduced in each 5 year period through 2020-2030 starting with the main cities of the country: Piura, Arequipa, Chiclayo, and Trujillo. Then, this could be further expanded nationwide. Lima's public transport could also be enhanced with the development of 4 new Metro lines. We estimate accumulated investment of $9 billion (a net present value of $5.5 billion with a discount rate of 10%) for the infrastructure building and the development of enabling conditions by 2050. Beyond the development of new public transport infrastructure, the quality of service should be improved to create a model of public transport as attractive compared to private vehicles. Only a combination of infrastructure development and service quality improvements ensuring better safety, higher speed and lower cost than personal car is able to change the population transport preferences.

These actions will allow cheaper, safer and more energy efficient transportation, which will have a growing demand as shown in the first experiences of BRT and Metropolitan train.

Change of vehicle technologies: electricity as a new fuel. It is possible to electrify the car stock; we project 85% battery electric and 10% plug-in hybrid cars by 2050. For other road vehicles, we target 70% of electric buses and 80% of two wheelers. Pilot programs for electric cars and two wheelers will be developed in Lima, then it will be scaled to the other main cities by 2030, and later will be developed nationwide. We estimate a necessary accumulated investment of $15.5 million (a net present value of $8.6 million with a discount rate of 10%) for the development of the policy and pilot programs by 2050. The penetration of electric motorization will depend in the reduction of fixed costs of these kinds of technologies. Also, it will differ in each Peruvian state due to the household's revenues and the presence of electric charging stations. So national incentives schemes should be promoted, such as a scrapping bonus, to assure the competitive prices of these technologies with respect to fossil fuels vehicles. For buses, the concessions could be an efficient tool to ask for the operation of vehicles with low GHG emissions, e.g. powered with electricity or fuelled with biofuels. Furthermore, the existing old collective taxis and microbuses need to be retired and

Figure 37. Passenger Transport Emissions by Type of Energy

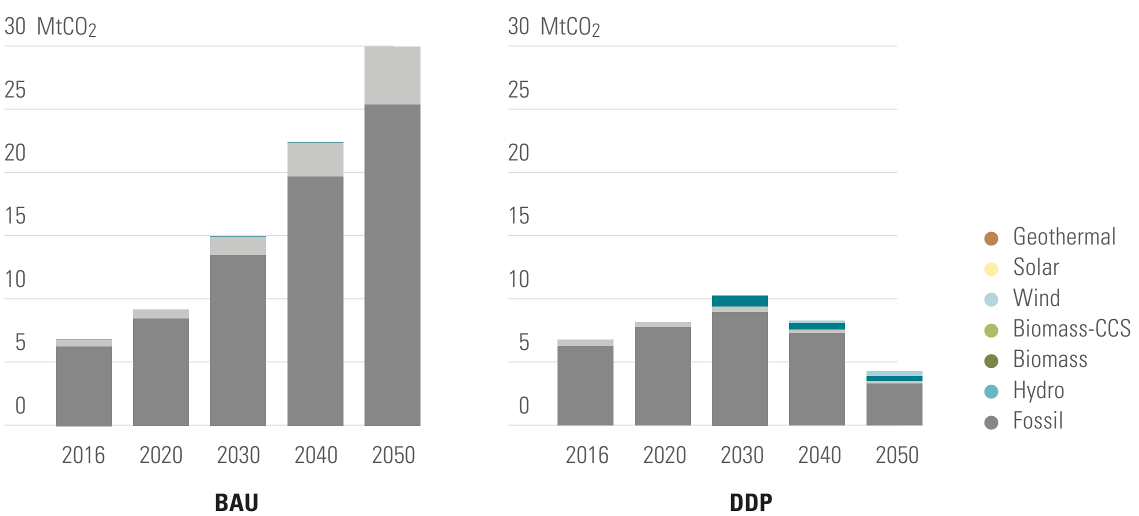
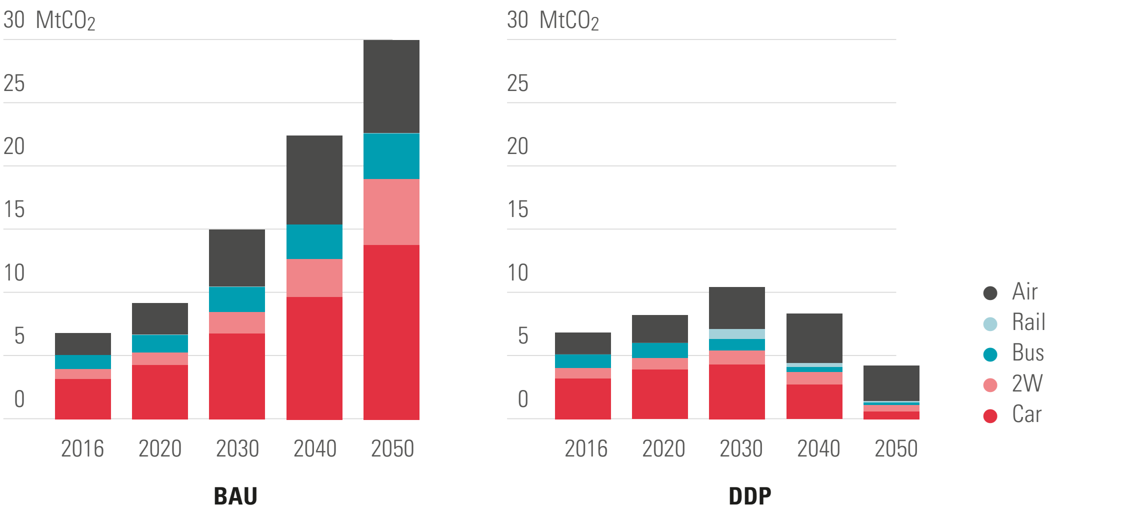


Figure 38. Passenger Transport Emission by Type of Transportation



this could be supported with a specific company-registered scrapping subsidy to buy low-carbon vehicles. At the same time, this could also help regulate this current informal form of public transport. As planned already by ATU, the retirement of collective taxis and microbuses in Lima will start from 2020 and will be extended in the rest of the country after 2030.

Energy alternative: Biokerosene and decarbonization of electricity. The introduction of biokerosene is needed in air transport with the current technological knowledge. However, this will need to be imported at first due to the lack of national production infrastructure. In 2050, 30% of the aviation fuel consumption should be biokerosene if we want to keep up with the demand of air travel and reduce national transport emissions. In addition, the electrification of transport is only an efficient lever if the electricity production is decarbonized. This requires removing fossil fuels (coal, oil and natural gas) as much as possible and to develop new renewables energies like wind and solar power. By 2050, renewable production could increase from 56% to more than 94% of the national electricity production and move the carbon content of electricity from 209 gCO_2/kWh to 30 gCO_2/kWh. This cleaner production could be achieved with higher quantity and frequency of national concessions auctions. We estimate accumulated investment of $0.4 million (a net present value of $0.3 million with a discount rate of 10%) for the planification and development of a low carbon transport concessions auctions strategy by 2050.

Teleworking as a game changer. Reducing the number of kilometres travelled for work purpose could be achieved with teleworking. For example, two days of telework affecting 50% of metropolitan population and 25% of non-metropolitan areas could reduce the demand of total kilometres travelled by 20% in metropolitan areas and by 10% in non-metropolitan areas. However, communications of the benefits of this action should be applied to increase the quantity of days and business that apply teleworking. An option could be the introduction of policies which allows the digitalization business activities, it would make easier the change of working behaviour. We estimate accumulated investment of $0.3 million (a net present value of $0.2 million with a discount rate of 10%) for policy development and socializing activities by 2050. [F37]

The deep decarbonization pathway allows the reduction of accumulated emissions from the AFOLU and passenger transport sectors by 2,125 Mt CO_2 eq. This represents a reduction of 40% compared to the BAU scenario. By 2050, the reduction will be reduced by -73%%, from 195.189 Mt C02 eq. to 51.920 Mt CO_2 eq. Despite the additional effort that this new pathway to decarbonization represents, net-zero emissions won't be achieved by 2050; it shows that a real transformational change is necessary for the different sectors with a more aggressive proposal of policies that will allow reaching this objective by 2050. It highlights the need for the support of international cooperation for the design, evaluation and implementation of these policies to achieve net-zero emissions by 2050.

The models

The POLYSYS - Peru model was used for the AFOLU analyses to consider feedbacks across sectors and measure the impacts in GDP between forestry and agriculture. In the passenger transport sector the ASIF model was used to measure the impacts of the change in transport demand, fuel consumption and technology use. Please contact the authors for questions.

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The 2050 Pathways Platform is a multi-stakeholder initiative launched at COP 22 by High-Level Climate Champions Laurence Tubiana and Hakima El Haite to support countries seeking to develop long-term, net zero-GHG, climate-resilient and sustainable-development pathways. Designed as a space for collective problem-solving, the platform will also build a broader constellation of cities, states, and companies engaged in long-term low-emissions planning of their own, and in support of the national strategies.

2050pathways.org