LIABILITY FOR CLIMATE CHANGE IMPACTS: THE ROLE OF CLIMATE ATTRIBUTION SCIENCE[1]

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1. INTRODUCTION

In 1941 a devastating flood swept through the Andean city of Huaraz (Peru), killing at least 1,800 inhabitants.[2] The 'glacial lake outburst flood' occurred as the natural dam that retained Laguna Palcacocha failed, releasing a torrent of water and sediment down the Cojup valley and onto the city.[3] Recent research suggested that this mid-20th Century disaster may have been an early impact of human-caused climate change, as the glaciers at the head of Laguna Palcacocha retreated from their pre-industrial positions, allowing the lake to swell in the wake of their retreat.[4]

Since the mid-20th Century, climate change has forced the Palcaraju and Pucaranra glaciers to recede a kilometre further uphill.[5] In place of these glaciers, Laguna Palcacocha has expanded 34-fold in volume[6] and once again threatens to

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[2] S. WEGNER, 'Lo Que El Agua Se Llevó: Consecuencias y Lecciones Del Aluvión de Huaraz de 1941' (2014) <https://ia802205.us.archive.org/2/items/NotaTecnica7/Nota Tecnica 7 final.pdf> accessed 28.07.2019.

[3] M. MERGILI and others, 'Reconstruction of the 1941 GLOF Process Chain at Lake Palcacocha (Cordillera Blanca, Peru)' (2020) 24 *Hydrology and Earth System Sciences* 93.

[4] R. STUART-SMITH and others, 'Increased Outburst Flood Hazard from Lake Palcacocha Due to Human-Induced Glacier Retreat' (2021) 14 *Nature Geoscience* 85.

[5] ibid.

[6] C. PORTOCARRERO RODRÍGUEZ, 'The Glacial Lake Handbook: Reducing Risk from Dangerous Glacial Lakes in the Cordillera Blanca, Peru' (2014) <https://pdf.usaid.gov/pdf_docs/PBAAA087.pdf> accessed 30 September 2018.

flood the city of Huaraz, now a city of 140,000 people.[7] In response, the local authorities are planning to build enhanced hazard-reduction measures at the lake. To recover part of the risk-reduction costs, a local resident filed a lawsuit in the District Court in Essen (Germany).[8] In the claim, Saúl Luciano Lliuya is seeking compensation for the pro rata cost of measures taken to protect his property against the flood hazard from RWE, a German energy company and Europe's largest emitter of carbon dioxide,[9] based on Article 1004 of the German Civil Code, which concerns liability for nuisance.

In the lawsuit, Lliuya claims that climate change caused the increased flood risk that Huaraz faces today, and that RWE's contribution to historical greenhouse gas emissions – estimated to be 0.47% of all human-caused emissions[10] – renders them partially responsible for the costs of the flood prevention measures. Applying a proportional approach to allocating contributions to total damages, the claim seeks 0.47% of these costs from RWE. The case was initially dismissed by the District Court of Essen on the grounds that the high number of contributors to climate change prohibits the attribution of damages to individual entities.[11] However, the Higher Regional Count of Hamm accepted that the case was conclusively argued on appeal and initiated an evidentiary phase in which it would evaluate two scientific questions: first, whether it is indeed the case that the claimant's property is threatened by the potential flood; and second, whether a causal link can be established between RWE's emissions and the heightened flood risk.[12]

Lliuya v. RWE is just one of over 2,000 cases brought before courts worldwide on matters related to climate change.[13] Climate lawsuits are typically brought in response to (perceived) governance gaps; accordingly, they may challenge policies that contravene the rights of future generations,[14] fail to address the needs of

[7] C HUGGEL and others, 'Anthropogenic Climate Change and Glacier Lake Outburst Flood Risk: Local and Global Drivers and Responsibilities for the Case of Lake Palcacocha, Peru' (2020) 20 *Natural Hazards and Earth System Sciences* 2175; M SOMOS-VALENZUELA and others, 'Modeling a Glacial Lake Outburst Flood Process Chain: The Case of Lake Palcacocha and Huaraz, Peru' (2016) 20 *Hydrology and Earth System Sciences* 2519.

[8] The case is now on appeal at the Higher Regional Court of Hamm.

[9] As of 2021, scope 1 emissions only. See https://www.greenpeace.de/publikationen/kurzanalyse_rwe_-_vom_winde_verweht_maerz_2021.pdf [accessed 20.06.2022].

[10] R. HEEDE, 'Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010' (2014) 122 *Climatic Change* 229.

[11] Lliuya v. RWE AG District Court of Essen Judgment of 15 December 2016—2 O 285/15.

[12] Lliuya v RWE AG (Az 5 U 15/17 OLG Hamm). At the time of writing, the case is pending and the court and its appointed experts recently completed a site visit to Laguna Palcacocha in Peru.

[13] J. SETZER and C. HIGHAM, 'Global Trends in Climate Change Litigation: 2022 Snapshot' (2022) <https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/06/Global-trends-in-climate-change-litigation-2022-snapshot.pdf> [accessed 21.08.2022].

[14] E.g., *Neubauer et al. v. Germany; Future Generations v. Ministry of the Environment and Others*.

vulnerable groups,[15] fall short of international-law or human-rights obligations,[16] are not self-consistent, for instance by being incommensurate with other legal duties and targets,[17] or contravene domestic-law or international obligations.[18] Further claims have been brought in response to the non-provision of recourse for individuals or communities suffering disproportionate impacts of climate change.[19] More generally, climate-related legal action can bridge the gap between policies introduced at the international level and the duties of individual states or corporations in contributing to the objectives of those policies.

Climate science has a central role to play in many cases related to climate change: *Lliuya v. RWE* is an exemplar of this. As the demands on courts to resolve issues related to climate change grow, judges are being asked to adjudicate claims that introduce climate science to demonstrate that defendants' actions interfere with rights owed to claimants. In many climate lawsuits, legal concepts such as human rights, torts, nuisance, and constitutional duties are invoked, with scientific evidence used to show how pre-existing legal theories can be applied in the context of climate change.

The diversity of cases filed to date creates a wide range of scientific needs. In this chapter we focus on one specific type of scientific evidence – that provided by climate attribution science – and its (potential future) use in lawsuits seeking compensation for losses or adaptation costs resulting from climate change. Literature on causation in climate litigation has detailed the role that attribution science can play in improving the prospects of causal arguments in climate lawsuits.[20] Our contribution here builds on this literature. We also synthesise an analysis of existing case law related to climate change impacts, including the scientific facts introduced by parties to the case and judicial interpretation of these facts and an assessment of ongoing issues in the application of climate change attribution science in the context of litigation.

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[15] E.g., *Mex M v. Austria*.

[16] E.g., *Urgenda Foundation v. State of the Netherlands*; *Milieudefensie et al. v. Royal Dutch Shell plc.*, *R (oao Friends of the Earth) v Secretary of State for Business Energy and Industrial Strategy*.

[17] E.g., *ClientEarth v. UK*, *ClientEarth v. PGE*.

[18] E.g., *Save Lamu v. NEMA*, *Plan B v. Secretary of State for Transport*.

[19] E.g., *Lliuya v. RWE*, *Four Islanders of Pari v. Holcim*.

[20] BURGER, HORTON and WENTZ (n 25); BULLOCK (n 24); S. MARJANAC, L. PATTON and J. THORNTON, 'Acts of God, Human Influence and Litigation' (2017) 10 *Nature Geoscience* 616; MARJANAC and PATTON (n 25); KYSAR (n 25); M. ALLEN and others, 'Scientific Challenges in the Attribution of Harm to Human Influence on Climate' (2007) 155 *University of Pennsylvania Law Review* 1353; STUART-SMITH and others (n 25); P. MINNEROP and F. OTTO, 'Climate Change and Causation: Joining Law and Climate Science on the Basis of Formal Logic' (2020) 27 *Buffalo Environmental Law Journal* 49.

We proceed as follows. Part 2 provides a primer on litigation seeking compensation for climate-related losses and adaptation costs, for which a causal link between defendants' greenhouse gas emissions and costs incurred by claimants needs to be established. Part 3 introduces the field of climate attribution science, analyses characteristics of the science that relate to its legal interpretation, and evaluates its use and judicial interpretation in ongoing climate liability lawsuits. Climate liability cases have been unsuccessful for a wide variety of reasons, many of which concern legal issues rather than anything to do with the scientific facts presented.[21] However, in some cases, exploiting recent developments in climate science could have overcome obstacles to establishing causation and may have altered litigation outcomes. Part 4 describes a series of characteristics of attribution science that have been identified as potential obstacles to establishing legal causation and explains how these obstacles can be overcome through the synthesis of scientific insight and legal reasoning. Part 5 discusses the future of attribution science in climate litigation, not only in cases related to damages but also in the context of cases seeking to compel defendants to reduce their emissions. Part 6 concludes and closes with suggestions on how the prospects of the application of attribution science in climate litigation can be improved. Overall, our contribution is to set out the nature of climate change attribution science and clarify how this field of scientific inquiry can support causal argumentation in climate litigation.

2. COMPENSATION FOR CLIMATE-RELATED LOSSES AND ADAPTATION COSTS

The 2015 Paris Agreement represents a key outcome of over two decades of international negotiations on climate change and commits states to contributing to global goals on mitigation of, and adaptation to, the impacts of climate change. The Agreement also sets a thus-far unmet floor of USD 100 billion in annual finance to support mitigation and adaptation measures in developing states. However, the Paris Agreement provides no direct basis for financial compensation for climate-change impacts: the pre-amble to the Agreement states that the Parties '[agree] that Article 8 of the Agreement [which concerns loss and damage] does not involve or provide a basis for any liability or compensation'.[22] Climate change is already causing substantial humanitarian and economic harm worldwide, and its

[21] BURGER, HORTON and WENTZ (n 20).

[22] UNFCCC, 'Adoption of the Paris Agreement', *Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015* (2015) <https://unfccc.int/sites/default/files/resource/docs/2015/cop21/eng/10a01.pdf> accessed 23.12.2019.

impacts disproportionately affect vulnerable communities that have contributed among the least to historical greenhouse gas emissions.[23] Procedural practicalities notwithstanding, there is a moral argument for a legal response to the inequitable distribution between harmful actions and harms experienced: a governance gap exists that excludes those affected by climate change impacts through little fault of their own from receiving compensation from those causing these impacts.

The short history of efforts to apply tort, public nuisance, trespass, consumer protection[24] and other laws to obtain compensation for climate change impacts has not yet led to pay-outs.[25] Extant literature on the topic identifies various obstacles. In part, these challenges have arisen because the nature of climate change is unlike many other forms of legal interference. Firstly, the impacts of climate change, while experienced unequally, affect everyone to a greater or lesser extent. In some jurisdictions, claimants must have suffered losses that are different in kind or degree to those affecting the general public to have standing, which may introduce obstacles given the widely distributed nature of climate change impacts. Secondly, climate change impacts result from the combined actions of all greenhouse gas emitters and so challenges exist in distinguishing legally between those entities that may be held liable for impacts (a 'defendant class'), and those who cannot.[26]

Finally, there is the challenge of proving causation, which our contribution concerns. Scholars have argued[27] that this obstacle to the success of litigation on

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[23] J BIRKMANN and others, 'Poverty, Livelihoods and Sustainable Development' in Hans-Otto Pörtner and others (eds), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press 2022); A. DIBLEY, T. WETZER, and C. HEPBURN, 'National COVID Debts: Climate Change Imperils Countries' Ability to Repay', 592 *Nature* 184 (2021).

[24] See, e.g., *Board of County Commissioners of Boulder County v. Suncor Energy (U.S.A.), Inc.*, *Anne Arundel County v. BP p.l.c.* Consumer protection law has been used to argue that claimants are due recovery for injuries sustained due to practices prohibited by state consumer protection acts. In *Anne Arundel County*, the claimant alleges that 'Defendants' marketing and promotion of fossil fuels are unfair, deceptive, and violate Maryland law because they deceived consumers in Anne Arundel County, led to the sale and consumption of fossil fuels that would otherwise not be consumed and thereby caused Anne Arundel County and its residents to suffer losses from, *inter alia*, rising sea levels, increased flooding, and extreme heat.' (Anne Arundel County v. BP p.l.c. No. C-02-CV-21-000565 (Md. Cir. Ct. 26 April 2021, p. 166, para. 302)).

[25] See, e.g. G. GANGULY, J. SETZER, and V. HEYVAERT, 'If at First You Don't Succeed: Suing Corporations for Climate Change', 38 *Oxford Journal of Legal Studies* 4 (2018).

[26] D. BULLOCK, 'Public Nuisance and Climate Change: The Common Law's Solutions to the Plaintiff, Defendant and Causation Problems' (2022) 85 *The Modern Law Review* 1136.

[27] S. MARJANAC and L. PATTON, 'Extreme Weather Event Attribution Science and Climate Change Litigation: An Essential Step in the Causal Chain?' (2018) 36 *Journal of Energy & Natural Resources Law* 265; M. BURGER, R. HORTON and J. WENTZ, 'The Law and Science of Climate Change Attribution' (2020) 45 *Columbia Journal of Environmental Law* 57; R. STUART-SMITH and others, 'Filling the Evidentiary Gap in Climate Litigation' (2021) 11 *Nature Climate Change*

climate change impacts is derived from (1) the abundance of greenhouse gas emitters and the general fungibility of their emissions in contributing to global warming, and consequently to specific impacts, (2) the underlying chance that extreme weather events could have occurred without the contribution of human influence, (3) the relative novelty of the attribution science evidence that can address these issues, (4) the potential sensitivity of results to the framing of attribution questions and therefore how attribution methods are applied, (5) the metrics used to present attribution results, and (6) uncertainty in climatic observations and modelling. Below we explain how the combination of scientific developments and legal interpretation can resolve these concerns and, in principle, facilitate the success of causal claims in climate litigation. Specific causality tests arise most frequently in the context of damages claims and so this chapter focuses primarily on this type of claim.[28]

3. AN INTRODUCTION TO ATTRIBUTION SCIENCE AND ITS USE IN ONGOING CLIMATE LITIGATION

The impacts of climate change occur primarily as a result of rising global temperatures, which is a response to the combined effect of greenhouse gas and aerosol emissions. Since the mid-19th Century, changes in these emissions have resulted primarily from human activity.[29] Climate change is therefore different in nature to some other examples of harmful conduct, where a defendant's conduct can be connected directly and exclusively to the harm experienced. Nevertheless, recent research has developed methods that facilitate evaluation of the full causal chain from emissions of greenhouse gases through to the impacts of climate change.[30]

3.1. A PRIMER ON ATTRIBUTION SCIENCE

The general causal relationship between greenhouse gas emissions, rising global temperatures, and the manifestations of climate change in a range of impacts is widely established in the scientific literature, including in successive reports of the Intergovernmental Panel on Climate Change (IPCC). Such causal relationships

651; BULLOCK (n 24); D. KYSAR, 'What Climate Change Can Do about Tort Law' (2011) 41 *Environmental Law* 1.

[28] With the exception of Section 5.2.

[29] IPCC, 'Summary for Policymakers' in V. MASSON-DELMOTTE and others (eds), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press 2021).

[30] See, e.g., F. LOTT and others, 'Quantifying the Contribution of an Individual to Making Extreme Weather Events More Likely' (2021) 16 *Environmental Research Letters* 104040.

have been recognised by courts in existing climate lawsuits.[31] A greater challenge for establishing causation in court has been the issue of specific causation: whether the emissions of an individual entity can be said to have contributed to the losses suffered by the claimant. The existing body of cases seeking compensation for climate-related harms have rarely proceeded to the merits stage.[32] Nevertheless, the issue of establishing specific causation has presented an obstacle to meeting admissibility requirements in existing lawsuits,[33] and is considered to pose a substantial challenge when cases proceed beyond the admissibility stage.[34] These specific causation claims can be addressed by a sub-field of climate science known as 'attribution science'.

Climate science has advanced substantially in recent decades. Even in recent years, news coverage of extreme weather events would state that no individual event could be shown to be the result of climate change. This no longer reflects the state of the science. It is now possible to conclusively demonstrate the influence of climate change on many impacts occurring worldwide, be it individual heatwaves or storms, or the retreat of glaciers. A growing literature links these physical impacts to their health,[35] social, and economic[36] consequences. Recent studies have also linked the emissions of countries, companies, and individuals with a range of climate change impacts, including global-temperature and sea-level rise,[37] ocean acidification[38], and heatwaves.[39] Attribution studies can now span the full causal chain from the greenhouse gas emissions of individual entities,

[31] STUART-SMITH and others (n 20).

[32] With the notable exception of *Lliuya v. RWE*, in which the Regional Court of Hamm initiated an evidentiary phase in 2017, which remains pending at the time of writing.

[33] STUART-SMITH and others (n 20).

[34] T. BURMAN, 'A New Causal Pathway for Recovery in Climate Change Litigation?' (2022) 52 *Environmental Law Reporter*; BULLOCK (n 24).

[35] A. VICEDO-CABRERA and others, 'The Burden of Heat-Related Mortality Attributable to Recent Human-Induced Climate Change' (2021) 11 *Nature Climate Change* 492.

[36] D. FRAME and others, 'The Economic Costs of Hurricane Harvey Attributable to Climate Change' (2020) 160 *Climatic Change* 271.

[37] B. EKWURZEL and others, 'The Rise in Global Atmospheric CO2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers' (2017) 144 *Climatic Change* 579; A. NAUELS and others, 'Attributing Long-Term Sea-Level Rise to Paris Agreement Emission Pledges' (2019) 116 *Proceedings of the National Academy of Sciences* 23487.

[38] R. LICKER and others, 'Attributing Ocean Acidification to Major Carbon Producers' (2019) 14 *Environmental Research Letters* 124060.

[39] L. BEUSCH and others, 'Responsibility of Major Emitters for Country-Level Warming and Extreme Hot Years' (2022) 3 *Communications Earth & Environment* 7; S. LEWIS and others, 'Assessing Contributions of Major Emitters' Paris-Era Decisions to Future Temperature Extremes' (2019) 46 *Geophysical Research Letters* 3936; LOTT and others (n 29).

through the physical impacts of these emissions, to the societal impacts that result.[40]

Attribution science is a subfield of climate science that assesses the contributions of greenhouse gas emissions to climate related harms. In this way, attribution science provides a means of evaluating claims of specific causation in climate litigation. Within attribution science, we can distinguish between a series of subcategories. 'Source attribution' assesses the historical and ongoing greenhouse gas emission contributions of individual emitters, typically (though not necessarily) corporations or countries.[41] 'Climate change attribution' evaluates the effects of human activity and other drivers of climate change on components of the earth system. Although the attribution of extreme meteorological events is sometimes allocated to a separate category, here we use the term 'climate change attribution' to include studies that evaluate the relationship between greenhouse gas and aerosol emissions and the physical consequences of these emissions, including global temperature change, sea-level rise, extreme weather events and glacier retreat. Finally, 'impact attribution' has been used to describe the link between physical processes and their societal, economic, environmental, or humanitarian consequences.[42] Individual studies commonly evaluate only one of these three types of attribution, although recent studies have extended analyses to synthesise different components of attribution.[43]

Counterfactual analyses lie at the heart of attribution science, although the precise nature of these assessments differ between studies of extreme weather events and slow-onset processes. Slow-onset processes describe natural systems that respond gradually to climate change and are insensitive to short-term climatic variations. Detection and attribution studies of such changes have evaluated the influence of climate change on glacier retreat[44] and melt,[45] sea-level rise,[46] mean lake

[40] F. OTTO and others, 'Causality and the Fate of Climate Litigation: The Role of the Social Superstructure Narrative' (2022) *Global Policy*.

[41] See e.g., HEEDE (n 10).

[42] BURGER, HORTON and WENTZ (n 20).

[43] See e.g., S. LI and F. OTTO, 'The Role of Human-Induced Climate Change in Heavy Rainfall Events Such as the One Associated with Typhoon Hagibis' (2022) 172 *Climatic Change* 7; LOTT and others (n 29); EKWURZEL and others (n 36).

[44] STUART-SMITH and others (n 4); G. ROE, M. BAKER and F. HERLA, 'Centennial Glacier Retreat as Categorical Evidence of Regional Climate Change' (2017) 10 *Nature Geoscience* 95.

[45] G. ROE, J. CHRISTIAN and B. MARZEION, 'On the Attribution of Industrial-Era Glacier Mass Loss to Anthropogenic Climate Change' (2021) 15 *The Cryosphere* 1889.

[46] NAUELS and others (n 36); A. SLANGEN and others, 'Anthropogenic Forcing Dominates Global Mean Sea-Level Rise since 1970' (2016) 6 *Nature Climate Change* 701.

temperatures,[47] and regional temperature change.[48] These studies typically assess the likelihood that an observed change can be explained by natural factors alone or calculate the contributions of anthropogenic and natural factors to the observed change.

In parallel with these developments, methods for extreme-event attribution studies have been developed to assess human influence on individual meteorological events, including storms, droughts, heatwaves, and floods.[49] Extreme event attribution studies use observations and climate models to simulate how frequently events of at least a given intensity would be expected to occur in the present climate and in a counterfactual climate without human greenhouse gas or aerosol emissions. Accordingly, the role of human influence on changing the probability of such events can be quantified. The same methods can also assess the attributable change in the magnitude of an event of given probability. For instance, in a study of the June 2019 heatwave in France, Vautard et al. (2020) found that the probability of a heatwave occurring with temperatures at least as hot as those observed had increased by 180 times as a result of anthropogenic climate change. Alternatively, using the intensity-based framing, the same study found that had a heatwave of equal probability occurred in the climate of 1901, temperatures would have been 4 °C lower.[50] Extreme event attribution studies typically present results for both formulations of the findings.[51]

A conceptually distinct but complementary approach to attribution has also been developed, known as the 'storyline approach'. Rather than quantifying attributable changes in event probabilities, the storyline approach focusses on the physical dynamics or state of the atmospheric circulation that led to the unfolding of a specific climate-related event. The question asked by this approach is: '*given the way event the event in question unfolded, how was this influenced by climate change?*'. As such the storyline approach assesses the effect of climate change on an event conditional on its dynamics and human-induced changes to the atmospheric conditions are not detectable by this approach. Instead, attribution studies

[47] R. WOOLWAY and others, 'Lake Heatwaves under Climate Change' (2021) 589 *Nature* 402.

[48] N. GILLETT and others, 'Attribution of Polar Warming to Human Influence' (2008) 1 *Nature Geoscience* 750.

[49] CARBON BRIEF, 'Mapped: How Climate Change Affects Extreme Weather around the World' (2022) <https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world> [accessed 21.08.2022].

[50] R. VAUTARD and others, 'Human Contribution to the Record-Breaking June and July 2019 Heatwaves in Western Europe' (2020) 15 Environmental Research Letters 094077.

[51] S. PHILIP and others, 'A Protocol for Probabilistic Extreme Event Attribution Analyses' (2020) 6 *Advances in Statistical Climatology, Meteorology and Oceanography* 177.

applying the storyline approach focus on how the effects of these dynamical conditions were altered due to human-induced changes to atmospheric thermodynamics.

Answers provided by the storyline approach are more explanatory than statistical in linking causal factors to the magnitude or impact of an event. They may find, for example that natural variability was responsible for 50% of the magnitude of a given event, conditioned on the dynamical context of the observed event.[52] In a recent article, Lloyd & Shepherd discuss how the storyline approach could be aligned with legal reasoning on causation.[53]

3.2. ATTRIBUTION SCIENCE IN EXISTING CLIMATE LIABILITY LAWSUITS

Attribution science has a clear role to play in evaluating the causal claims made in climate liability lawsuits. In a recent review of 73 cases across 14 jurisdictions, we and our co-authors assessed whether the growing recognition in academic literature of the role of attribution-science studies in litigation had translated into the use of such evidence by claimants.[54] We found that while the quality and specificity of evidence had improved in recent cases, the scientific evidence cited typically lagged behind the state-of-the-art in climate science, and, in some instances, this impeded the success of causal claims.[55] In general, courts have accepted that greenhouse gas emissions cause climate change as a whole with IPCC evidence frequently cited to establish such general causal relationships.

Claimants have encountered greater challenges in establishing specific causal links between emissions of individual defendant entities and losses. While this is by no means the case for all claims, in some cases, claimants focused on impacts for which evidence of the role of climate change is not yet clear, or only just emerging, rather than those impacts most demonstrably attributable to climate

[52] T. SHEPHERD and others, 'Storylines: An Alternative Approach to Representing Uncertainty in Physical Aspects of Climate Change' (2018) 151 *Climatic Change* 555; E. LLOYD and T. SHEPHERD, 'Climate Change Attribution and Legal Contexts: Evidence and the Role of Storylines' (2021) 167 *Climatic Change* 28.
[53] LLOYD and SHEPHERD (n 52).
[54] STUART-SMITH and others (n 20).
[55] ibid.

change.[56] In many instances, attribution was simply presumed, rather than demonstrated with scientific evidence.[57] However, critically, these findings were not due to technical limitations preventing the development of required evidence. Rather, using the right scientific evidence could make successful litigation on climate change impacts feasible. Existing methodologies can provide scientific insights that may be sufficient to establish causal links between claimants' losses and defendants' emissions.[58]

4. CONSIDERATIONS FOR USING ATTRIBUTION SCIENCE IN COURT

Parties to climate lawsuits are in the unusual position of not only being able to support claims with a large body of scientific research on climate change and its impacts, but also being able to draw on the findings of the IPCC. The IPCC's reports synthesise the scientific community's consensus understanding of climate change. Since IPCC reports undergo a process of government review and approval, they are an assessment of the state of the science that is accepted by all governments and are therefore considered authoritative in court.

As such, IPCC reports are highly valuable sources of evidence, and their findings are widely considered to be of near-unimpeachable credibility. The IPCC's assessments cover a wide range of topics including projections of future climate change impacts, attribution of observed climate change, and mitigation pathways consistent with limiting global warming to various levels. The IPCC reports do not generally provide new assessments but review the existing literature and draw global and regional conclusions based on published research. For instance, the Working Group I contribution to the IPCC's Sixth Assessment Report, published in 2021, assessed regional changes in hot extremes, heavy precipitation and agricultural and ecological drought. The report also provided an assessment of the confidence in the human contribution to these observed changes, grounded in the attribution science literature.[59] IPCC reports also provide location-specific examples and case studies derived from peer-reviewed literature. However, these examples are not comprehensive and conclusions are typically drawn on global or regional scales, supporting findings of general causation.

[56] ibid. One such example is the impact of climate change on tropical cyclones, which is complex and for which evidence is still relatively limited (but emerging). See e.g. LI and OTTO (n 43).
[57] STUART-SMITH and others (n 20).
[58] ibid.
[59] IPCC (n 29). See Figure SPM.3 for more details.

IPCC reports' findings on attribution of climate change impacts therefore provide a robust general basis for causal claims. However, these reports may not be sufficient to support findings for specific causation if they do not provide assessments of the role of anthropogenic greenhouse gas emissions in causing the individual impacts that result in a claimant's losses, although they may cite papers that do. Similarly, government climate reports may summarise findings from a range of other sources to produce national or sub-national scale assessments, but depending on the nature of the impact, they may also not provide information at the level of granularity needed for specific causation. IPCC and other assessments therefore have a crucial role to play in providing a scientific basis for causal claims and can lend credibility to more specific claims, but they are not usually sufficient to establish legal causation in an individual case. This underlines the ongoing importance of dedicated attribution studies for supporting specific causal claims in climate litigation.

The availability of attribution-science evidence to support legal arguments has rightly been recognised as an important development that has raised the prospect of courts finding a causal relationship between greenhouse gas emissions and climate change impacts in climate lawsuits. However, the application of this evidence to establish causation is subject to several considerations. Here, we explore the scientific understanding and legal implications of (1) the non-exclusive contribution of human influence to extreme events, (2) the assumption that greenhouse gases are fungible in their contribution to climate change impacts, which underlies the use of market share theory for allocating contributions to harm, (3) the existence of multiple metrics for attributing climate-related harms to human influence, (4) the influence of methodological choices on attribution findings, and, in common with most fields of scientific inquiry, (5) uncertainty in attribution assessments. Our assessment builds on existing literature on legal causation.[60] We explain that these considerations are relevant for understanding how causal argumentation can be developed in legal contexts and need not be an obstacle to establishing causation in court.

4.1. SOME CLIMATE-RELATED HARMS MIGHT HAVE HAPPENED ANYWAY

Heatwaves, storms, and droughts are not new phenomena. Such events have occurred throughout history and would have continued to do so, but, in many instances, with lower severity or frequency if not for human-induced climate change.

[60] We note that across most common and civil law jurisdictions similar concepts of causation are applied, even though the standards of proof and precise formulation of causation tests may vary.

By contrast, human-induced climate change is the main driver of observed sea-level rise[61] and the mass loss[62] and retreat of mountain glaciers has been attributed directly to human influence on the climate.[63] Due to the direct relationship between greenhouse gas emissions and slow-onset impacts, it has been suggested that litigation focused on such impacts would be more likely to succeed.[64] Nevertheless, the multiplicity of contributors to climate change means that in almost all settings, it is not possible to meet the stringency of a 'but for' test: that absent a single defendant's conduct, the claimant's losses would not have occurred.[65] Even so, existing literature on climate litigation has also indicated the viability of establishing causation through applying other causation tests for both meteorological events and slow-onset changes.[66]

The facts that there is an underlying chance that harmful events could have occurred in the absence of the combined activities of greenhouse gas emitters, and the numerosity of contributors to greenhouse gas emissions are not unique to climate change. Courts are well versed in assessing causal claims in settings where defendants' activities have increased, rather than created risks. In evaluating causal claims pertaining to negligence, strict liability, and the tort of nuisance, modified causation rules assess defendants' contribution to the infringement of rights. Accordingly, as is the case for those contributing to climate change, individual defendants need only to have contributed to claimants' impacts for causation to be established.[67]

To assess causal claims, evidence is assessed against a 'standard of proof' that determines the strength of a scientific relationship needed for causation to be established. The standard of proof used for evaluating probabilistic causal claims is formulated differently across jurisdictions, but may amount to a substantively similar approach. It can, however, be difficult to assess exactly how comparatively stringent thresholds for causation are across jurisdictions. In general, the U.S., England, Ireland, Denmark, and Lithuania adopt a 'more probable than not' standard, in which a doubling of the probability of harm is needed to establish causation. Austria and the Netherlands adopt a 'high probability' and 'reasonable degree of

[61] V EYRING and others, 'Human Influence on the Climate System' in V MASSON-DELMOTTE and others (eds), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press 2021).

[62] ROE, CHRISTIAN and MARZEION (n 45).

[63] STUART-SMITH and others (n 4); ROE, BAKER and HERLA (n 44).

[64] BURMAN (n 34).

[65] BULLOCK (n 20); KYSAR (n 20); MINNEROP and OTTO (n 20).

[66] MARJANAC and PATTON (n 20); MARJANAC, PATTON and THORNTON (n 20); MINNEROP and OTTO (n 20); BURGER, HORTON and WENTZ (n 20).

[67] MARJANAC, PATTON and THORNTON (n 20); MINNEROP and OTTO (n 20).

certainty' standard, respectively. In Germany a near certainty standard may be applied, but often judges simply need to be convinced of the existence of a causal link. Other continental European jurisdictions may adopt higher standards of proof: in Bulgaria and Spain certainty is expected, in Greece, France, Poland, and Italy a judge must be convinced that the causal link exists.[68]

4.2. THE FUNGIBILITY OF GREENHOUSE GASES

Once greenhouse gases from one source are emitted, they become mixed in the atmosphere with those from other sources. The combined effect of these emissions is to raise global temperatures, which, in turn, results in regional warming and individual impacts such as amplified weather events or glacial retreat. As a consequence, it is not possible to ascertain which greenhouse gases, emitted by whom and from where resulted in a given impact: climate change impacts result from the combined contributions of all emitters. This underlies the application of market share theory, also used in tobacco and pharmaceutical litigation, as a legal approach for allocating contributions to harm. Accordingly, an entity's contribution to an impact is calculated as equal to their proportional contribution to emissions as a whole, irrespective of where or when the emissions were produced. Despite this simplification, the approach is common in contexts where losses derive from multiple entities' action in a linear or nonlinear fashion, because it reduces evidentiary challenges when allocating damages. For extreme weather events this approach is well supported scientifically: changes in extreme weather events evolve in step with global and regional temperature rise, and therefore near-concurrently with emissions.[69]

However, for other climate change impacts that display lagged responses to temperature change and emissions, such as sea-level rise and the retreat of mountain glaciers, this relationship is more complex. These slow-onset changes respond to climatic perturbations over a period of decades (for mountain glaciers) to centuries-to-millennia (for sea-level rise).[70] Consequently, recent emissions will only

[68] M. INFANTINO and E. ZERVOGIANNI, *Causation in European Tort Law* (Cambridge University Press 2017) 611–612.

[69] S. SENEVIRATNE and others, 'Weather and Climate Extreme Events in a Changing Climate' in V. MASSON-DELMOTTE and others (eds), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press 2021).

[70] T. JÓHANNESSON, C. RAYMOND and E. WADDINGTON, 'Time-Scale for Adjustment of Glaciers to Changes in Mass Balance' (1989) 35 *Journal of Glaciology* 355; A. GRINSTED, J. MOORE and S. JEVREJEVA, 'Reconstructing Sea Level from Paleo and Projected Temperatures 200 to 2100 Ad' (2010) 34 *Climate Dynamics* 461; M. MENGEL and others, 'Future Sea Level Rise Constrained by Observations and Long-Term Commitment' (2016) 113 *Proceedings of the National Academy of Sciences* 2597.

just have begun to contribute to sea-level rise, whereas greenhouse gases produced decades ago will have induced more substantial changes. As such, for slow-onset processes, while the market share approach to assessing individual entities' contributions to impacts is generally a useful approximation, it may need to be adapted as the assumption that emissions are fungible is no longer strictly accurate.

While the market-share approach is useful for allocating contributions to impacts in a range of settings, it is also possible to quantify the contributions made by individual emitters of greenhouse gases to climate change impacts. Such studies typically assess the difference in an impact between a climate with observed greenhouse gas emissions, and a climate without the emissions of the entity in question. Alternatively, studies may quantify the effects of the contribution made by an individual emitter as compared with a natural climate without any human influence. Recent literature has linked climate change impacts to the emissions of individual corporations, states, and even individuals. These studies quantified the contributions of greenhouse gas emitters to global-mean temperature change[71], existing[72] and future[73] global sea-level rise, ocean acidification[74], and the occurrence probability of extreme weather events[75]. The findings of such studies are sensitive to framing choices for how the attribution analysis is conducted. For instance, the contribution of an individual emitter may be assessed differently if it is quantified by comparing the present climate with one in which their emissions had not happened or by comparing a natural climate with one in which only their emissions are included.[76] Further, choices need to be made regarding which emissions of a defendant should be included which may be determined by, for instance, the timeframe over which defendants may be held liable for their emissions, or the emissions scopes that individual defendants can be held responsible for.[77]

The scientific feasibility of attributing climate impacts to individual emitters has the potential to support causal claims and demonstrate that individual emitters' contributions are measurable and non-zero. However, it has also been suggested that such advances could add to rather than simplify the challenges in establishing

[71] R. SKEIE and others, 'Perspective Has a Strong Effect on the Calculation of Historical Contributions to Global Warming' (2017) 12 *Environmental Research Letters* 024022.
[72] EKWURZEL and others (n 37).
[73] NAUELS and others (n 37).
[74] LICKER and others (n 38).
[75] F. OTTO and others, 'Assigning Historic Responsibility for Extreme Weather Events' (2017) 7 *Nature Climate Change* 757; LOTT and others (n 29); LEWIS and others (n 38); BEUSCH and others (n 38).
[76] OTTO and others, 'Assigning Historic Responsibility for Extreme Weather Events' (n 75).
[77] SKEIE and others (n 71). This is also the case when applying market share theory.

causation. Thomas Burman argues that studies assessing the contribution of individual emitters to climate harms may remove the option to seek more relaxed standards of causation, as these are typically granted in instances of causal uncertainty, where demonstrating which entities caused the harm would not be possible.[78] Secondly, such studies draw attention to the fact that the contributions of individual defendants can be very small. Consequently, there is the risk that lower standards of proof will be unavailable to claimants and the size of a defendant's contribution will not be sufficient for meeting stricter causation requirements.[79] It also remains the case that only in highly specific settings would one defendant's contribution be sufficient to cause impacts that would not otherwise have occurred. Such an impact might be a river that overtops its embankment, flooding a claimant's home, and for which a very small reduction in rainfall would have been sufficient for the floodwaters to be retained within the river channel. The improbability of such a specific example occurring in practice underlines the challenges to establishing a 'but for' causal link to an individual defendant in climate litigation. However, the application of other legal concepts such as market share theory may facilitate the allocation of liability in settings where individual contributions to emissions are not large enough to themselves satisfy a 'but for' test.

The findings of attribution studies demonstrating individual emitters' contributions to climate harms are hardly surprising. Such findings are consistent with pre-existing knowledge on the (generally, proportionately small) historical contributions of individual greenhouse gas emitters to climate change[80] combined with the assessment of the contribution of human influence as a whole to a range of climate impacts. Moreover, in some past lawsuits, courts have held that it would not be possible for claimants to demonstrate what, if any, contribution an individual defendant had made to their losses.[81] Developments in this area of research renders such statements outdated.

4.3. METRICS FOR REPRESENTING HUMAN INFLUENCE ON CLIMATE IMPACTS

A further set of considerations concern the presentation of attribution findings themselves. For meteorological events, as noted above, attribution studies can assess the extent to which climate change affects the likelihood of an event occurring that is greater than or equal to a given magnitude, or the attributable change in intensity of an event of given probability. The methods applied for either framing

[78] BURMAN (n 34).
[79] ibid.
[80] HEEDE (n 10).
[81] STUART-SMITH and others (n 20).

of the analysis are basically identical and attribution studies typically present both intensity and probability-based approaches to conducting the analysis.

The existence of two metrics for representing the findings of attribution studies that may indicate a qualitatively different role of climate change raises the prospect of a battle between contrasting but apparently valid assessments of the effects of greenhouse gas emissions. For instance, a recent study of a heatwave in Siberia in 2020 found that it would have been almost impossible for temperatures to have been as hot as they were if not for human influence on the climate.[82] When considering how much cooler the equal-likelihood event would have been in the absence of climate change, the study found that temperatures would have been a few degrees centigrade lower than observed in the real event: cooler, but still hot.[83] Both metrics show that natural climate variability plays a role, but the heatwave and associated impacts has been amplified in likelihood and intensity due to climate change.

Scientifically, intensity and likelihood-based metrics are two sides of the same coin. However, the different formulations may be subject to different causation tests and may not lead to the same interpretation by courts. Courts must therefore understand how these metrics relate to one another and their relative explanatory power for the role of climate change in causing losses in question. If it were the case that attribution statements based on these two metrics are interchangeably precise representations of the effect of climate change on impacts of equal legal relevance, this could introduce an obstacle to establishing causation in court.

As climate change attribution studies have been extended from considering the role of human influence in physical hazards to also including their social, physiological and economic impacts, recent literature has queried the applicability of probability-based assessments of human influence as they concern a 'class of events', rather than the specific impact experienced by claimants.[84] In other words, assessments of changing probabilities quantify changes in the chance of *exceeding a threshold value*. This would correspond to the change in probability of the impacts suffered by a claimant only if there is a threshold value above which the claimants' losses occur. Probability-based assessments can therefore assess the effect of climate change in settings where there is a discontinuity in the relationship

[82] A. CIAVARELLA and others, 'Prolonged Siberian Heat of 2020 Almost Impossible without Human Influence' (2021) 166 *Climatic Change* 9.
[83] ibid.
[84] S. PERKINS-KIRKPATRICK and others, 'On the Attribution of the Impacts of Extreme Weather Events to Anthropogenic Climate Change' (2022) 17 *Environmental Research Letters* 024009.

between a physical hazard (such as rainfall intensity) and the resulting impacts (for instance, whether or not a river bursts its banks and floods the surrounding area).[85]

By contrast, continuous hazard-impact relationships, such as the impact of temperature on mortality,[86] may be more accurately described by intensity-based framings of attribution findings: it is generally not the case that were temperatures below a threshold value none of the observed heat-related deaths would have occurred.[87] Probability-based assessments do not account for impacts (e.g., heat-related deaths) occurring below the threshold evaluated in the study. The intensity-based approach to conducting attribution analyses can also circumvent the concerns raised by Perkins-Kirkpatrick et al. as, rather than evaluating human influence on a class of events, it assesses the changed intensity of events of a specific probability. Different attribution metrics can provide apparently contrasting assessments of the role of climate change in an impact. However, the specific question asked by these framings of attribution results differs: the metric (intensity or probability-based) used should be tailored to the setting in which it is being applied. To date, most existing literature[88] on the use of attribution-science evidence to support causal claims has focused on legal approaches to applying attribution evidence of changing event probabilities.[89] Future legal research could consider how causal analysis in law may respond to attribution of changing event intensities.

4.4. FURTHER CHARACTERISTICS OF ATTRIBUTION SCIENCE

In common with many forms of scientific inquiry, the findings of attribution studies depend on methodological choices made in the analysis. Such choices include the 'event definition' used for meteorological and impact attribution studies, which describes the temporal and spatial scale of the analysis, and the parameters that will be analysed (such as which meteorological variables are assessed).[90] Attribution studies often provide sensitivity analyses to these definitions that quantify the extent to which the findings depend on these choices.

[85] ibid.

[86] A. VICEDO-CABRERA, F. SERA and A. GASPARRINI, 'Hands-on Tutorial on a Modeling Framework for Projections of Climate Change Impacts on Health' (2019) 30 *Epidemiology* 321.

[87] Except at the 'minimum mortality temperature' above which heat-related deaths occur and at which they do not.

[88] See e.g., BURMAN (n 34); MINNEROP and OTTO (n 20); MARJANAC and PATTON (n 20); MARJANAC, PATTON and THORNTON (n 20).

[89] For instance, in England & Wales, the 'doubling-of-the-risk test' allows courts to establish causation when evidence demonstrates that the likelihood of an event occurring was at least twice as high as a result of defendants' conduct.

[90] PHILIP and others (n 51).

Another charge occasionally levelled at attribution science is that the findings of these studies are uncertain due to limitations in models' abilities to accurately simulate the climate system and limited climatic observations to evaluate how well models perform in representing the climate. These challenges are by no means unique to attribution studies, but apply to studying the climate system in general, are widely documented, and similar considerations exist for most fields of scientific inquiry. Systematic approaches for quantifying the magnitude of uncertainties are deployed in attribution studies[91] and the sensitivity of results to these uncertainties can therefore be quantified.

5. THE FUTURE OF ATTRIBUTION SCIENCE IN CLIMATE LITIGATION

The now-substantial body of literature on climate change attribution has produced an increasingly comprehensive picture of the impacts of climate change. Hundreds of climate change attribution studies have been conducted worldwide.[92] These studies, combined with strong theoretical bases for understanding the effects of climate change on a wide range of physical phenomena, and across many regions, strengthen understanding of the extent to which impacts occurring around the world can be attributed to human influence. On the bases of the improved empirical and theoretical understanding of the impacts of climate change, the Sixth Assessment Report of the IPCC derived general understandings of the role of human influence in extreme weather events occurring in different regions, identifying regions where climate change is increasing / reducing the incidence of hot extremes, heavy precipitation, and agricultural and ecological drought, and regions where data or agreement between studies on the direction of change is limited.[93]

5.1. WILL FUTURE LAWSUITS REQUIRE SPECIFIC ATTRIBUTION STUDIES?

It is in the context of broader scientific understanding of the effects of climate change that specific attribution-science evidence is most useful. As noted above

[91] G. VAN OLDENBORGH and others, 'Pathways and Pitfalls in Extreme Event Attribution' (2021) 166 *Climatic Change* 13.
[92] CARBON BRIEF (n 49).
[93] Figure SPM.3 in IPCC (n 29).

and has been shown in detail elsewhere,[94] the exact results of attribution studies can be sensitive to the exact framing and methodological approach as well as the definition of the event. While this may not change the overall finding that climate change has altered event likelihood or intensity, individual attribution studies may still be challenged by some parties. The finding of a substantial role for human-induced climate change is strengthened by similar results from other studies in the same region.

As we explain above, the development of these general understandings of regional effects of climate change do not at this time appear to reduce the need for specific attribution studies if litigants are to establish causation in climate lawsuits. However, these understandings do provide the necessary general basis in which specific causal arguments can be grounded. Especially given the challenges that claimants have faced in past litigation, which have meant that lawsuits seeking compensation for the impacts of climate change have not yet been successful, the need for high-quality, specific studies that assess the causal link between claimants' losses and the emissions of defendants appears to remain necessary. Such studies can now be completed relatively quickly and initial results from 'rapid attribution' studies using peer-reviewed methods can be generated within days of an event occurring in some instances. Every new specific attribution study in turn adds to the body of literature and contributes to a general causal understanding (described by Minnerop & Otto as a 'distinctive causal field'[95]), strengthening future causal arguments. While the costs of commissioning attribution studies may be a concern to some litigants, such costs are typically far less than legal fees and this underlines the need for dedicated funding to support the development of scientific research that is relevant to climate litigation. Further, increased dialogue between the legal and scientific communities on the factual basis for causal claims may alert scientists to legally-relevant issues to which their research could contribute.

It is possible that attribution studies specific to claimants' injuries may not be needed to establish causation in future. However, it appears that the state of climate litigation remains someway away from this point. At the time of writing, courts have not yet recognised the existence of a specific causal relationship between greenhouse gas emissions and losses of a claimant in a lawsuit seeking compensation for climate-related harms.[96] Future developments may limit the need for specific attribution evidence to support every causal claim, due to a combination

[94] F. OTTO and others, 'The Attribution Question' (2016) 6 *Nature Climate Change* 813; MINNEROP and OTTO (n 26).
[95] MINNEROP and OTTO (n 20).
[96] STUART-SMITH and others (n 20).

of relaxed causal tests and a strengthened empirical and theoretical basis for assessing the likely contribution of climate change to a given physical event. The regional-scale assessments of the effect of climate change on a range of physical hazards, such as droughts, heavy precipitation and heatwaves provided in the Sixth Assessment Report of the IPCC (see Part 4) may facilitate this process in future. In the meantime, the need for clear scientific elucidation of the basis for causal claims appears to remain critical if causal claims are to succeed in courts.

5.2. ATTRIBUTION SCIENCE IN LITIGATION SEEKING EMISSION REDUCTIONS

Domestic climate policies worldwide remain insufficient to meet the goals of the Paris Agreement. Recent strengthening of climate pledges, if implemented in full (including targets that are conditional on the receipt of finance for emission-reduction measures) may be sufficient to limit global warming to 2 °C above pre-industrial levels.[97] However, the policies that have been introduced still lag the ambition of climate pledges that themselves are insufficient to meet the Paris Agreement's target of limiting warming to 1.5 °C. The International Energy Agency has stated that there is already enough installed fossil fuel infrastructure raise global temperatures to 1.5 °C above pre-industrial levels if installed infrastructure is used for its expected lifespan.[98] Even with widespread deployment of carbon capture and storage (CCS) and bioenergy for emissions abatement, already-operating, under construction and planned power plants will produce more emissions than are compatible with limiting warming to 2 °C.[99] In other words, new fossil fuel infrastructure is incompatible with the Paris Agreement, unless a commitment to decommission existing infrastructure is made.

In growing numbers of legal claims, claimants have argued that inadequate corporate or state emission reduction targets or policies, the approval of emitting infrastructure, or the permitting, financing, construction or operation of fossil fuel projects contravene a duty of care owed to claimants.[100] In such suits, the remedy requested is typically not damages, as in the cases highlighted above, but an injunction for strengthened emission reduction targets over a certain period, the

[97] M. MEINSHAUSEN and others, 'Realization of Paris Agreement Pledges May Limit Warming Just below 2 °C' (2022) 604 *Nature* 304.

[98] INTERNATIONAL ENERGY AGENCY, 'Net Zero by 2050: A Roadmap for the Global Energy Sector' (2021) <https://www.iea.org/reports/net-zero-by-2050> accessed 21.08.2022.

[99] Y. LU and others, 'Plant Conversions and Abatement Technologies Cannot Prevent Stranding of Power Plant Assets in 2 °C Scenarios' (2022) 13 *Nature Communications* 806.

[100] See, e.g., *Milieudefensie v. Royal Dutch Shell plc.*, *Sharma and others v. Minister for the Environment*.

withdrawal of planning permission for individual projects, or the cessation of public financing of fossil fuel infrastructure. While the nature of claims and therefore the scientific evidence that may be introduced to support them varies, there are two core elements of legal arguments that may require scientific input. The first is to establish that claimants are impacted by defendants' actions and that a positive ruling would reduce the impacts experienced. Such arguments are typically advanced to meet requirements for standing,[101] or in support of claims that a state has a duty of care to minimise or prevent climate change impacts.[102] The second is for claimants to show that the emitting activities of defendants, be it their entire climate policy or the approval of individual projects, are inconsistent with certain duties, such as those associated with the Paris Agreement or domestic legislation. Here, we discuss how attribution science evidence may be advanced in support of the first of these arguments.

5.2.1. How claimants are seeking mitigation action through the courts: an overview

'Systemic mitigation' cases describe those that seek to change government or corporate climate targets or policy and have included challenges to states' 2030 nationally determined contribution (NDC) to the Paris Agreement, domestic emission reduction targets prior to 2030, post-2030 targets, and carbon budgets allocations for specific periods.[103] These cases have been brought as rights-based, tort-based, and public law claims. Such claims challenge the absence of greenhouse gas emission reduction commitments in a given period, a state's failure to meet its own carbon budgets or emission-reduction targets, inconsistency between targets (for instance those covering different periods of time), the weakening of a

[101] BURGER, HORTON and WENTZ (n 20).
[102] L. MAXWELL, S. MEAD and D. VAN BERKEL, 'Standards for Adjudicating the next Generation of Urgenda-Style Climate Cases' (2022) *Journal of Human Rights and the Environment* 35.
[103] ibid.

state's emission-reduction target in contravention of the 'ratchet' mechanism introduced under Article 4 of the Paris Agreement,[104] inappropriate temporal distribution of mitigation effort,[105] excessive reliance on negative emissions technology,[106] and targets that fall short of a state's fair-share contribution to emission reductions under the Paris Agreement.[107]

Cases challenging individual projects on the grounds of their contribution to climate change have also been brought worldwide and are one of the most commonly employed legal strategies to address climate change. These cases have been brought on the grounds of constitutional, human rights, and administrative law, as well as invoking international obligations.[108] Such cases have included challenges to national or sub-national governments for either failing to reduce emissions sufficiently or for causing an increase in emissions. Litigation of this type has concerned planning permission for projects such as coal mines, power plants or airport expansion,[109] and public financing of fossil fuel infrastructure.[110] Other cases have been brought against corporations to block the construction of fossil fuel infrastructure,[111] or by corporations challenging the denial of permission for high-emitting projects.[112]

5.2.2. Scientific evidence for climate mitigation litigation

Mitigation-focused litigation generally seeks to advance claims that a defendant should act to limit the exposure of some (likely to be) affected party to the consequences of climate change.[113] Legal arguments made to this end include claims

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[104] Article 4 of the Paris Agreement states that 'Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition'; UNFCCC (n 22).

[105] Typically, inadequate short-term targets that leave a disproportionate component of emission reductions to subsequent decades.

[106] The reliance on negative emissions technology in climate targets may allow emitting assets to be built that would otherwise be adjudged incompatible with climate targets. However, there is no guarantee that these technologies will be technologically feasible, or if feasible, that they will be built. See, e.g., K. ANDERSON and G. PETERS, 'The Trouble With Negative Emissions' (2016) 354 *Science* 182.

[107] MAXWELL, MEAD and VAN BERKEL (n 103).

[108] J. SETZER and C. HIGHAM, 'Global Trends in Climate Change Litigation: 2021 Snapshot' (2021) <https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/07/Global-trends-in-climate-change-litigation_2021-snapshot.pdf> accessed 05.07.2021.

[109] E.g., *Plan B Earth v Secretary of State for Transport*; *Bennett v. Cumbria County Council*; *Save Lamu v. NEMA*.

[110] E.g., *Friends of the Earth v. UK Export Finance*; *Kang et al. v. KSURE and KEXIM.*

[111] E.g., *Client Earth v. PGE*.

[112] E.g., *Gloucester Resources Limited v. Minister for Planning*.

[113] This is, of course, a grossly reductionist statement – the nature of the legal grounds varies considerably. See J. SETZER and C. HIGHAM, (n 108).

that contributions to climate change violate, or risk violating, duties of care.[114] Duty of care is a tort law concept that describes the standard of reasonable care for legal entities in their treatment of third parties, particularly while performing acts that could foreseeably harm others. Similarly, to establish standing, claimants may need to demonstrate that the conduct of defendants (i.e., greenhouse gas emissions) has led to impacts that claimants are experiencing or are projected to experience. In these instances, climate change attribution and projections can support the assessment of past or future (conditional on scenarios of future greenhouse gas emissions) impacts of climate change. For instance, in the Application to the European Court of Human Rights in KlimaSeniorinnen v Switzerland, claimants sought to establish their victim status by arguing that they are already affected by 'dangerous climate change' in the form of mortality and morbidity associated with more extreme heat. Claimants argued that the risks of extreme heat to which they are exposed had been worsened by climate change, including due to the Swiss government's failure to make adequate emission reductions.[115] These arguments could be supported with attribution-science evidence demonstrating the impact of climate change on heat-related mortality and morbidity in the region where the claimants live.

We also note that other forms of climate change impact science may play a key role in such claims, notably projections of future impacts. In a lawsuit filed in 2021, Pabai Pabai and Paul Kabai, seek to protect their communities in the Torres Strait islands from harms associated with climate change, including sea-level rise and coastal erosion, ocean acidification, intensifying and more frequent extreme weather events, and harm to ecosystems and human health. In the case, pending in the Federal Court of Australia at the time of writing, the claimants used projections of future sea-level rise and other climate change impacts to demonstrate that the Australian government has failed to take steps to fulfil its duty of care to the Torres Strait islands communities, and therefore that the Australian government should increase its mitigation efforts and support for adaptation action.[116]

In recent rulings, courts have used climate-science evidence to find that even small contributions to climate change can be causally linked to impacts, thus providing claimants with standing to sue, or establishing a duty of care for defendants. In *Milieudefensie et al. v. Royal Dutch Shell*, the District Court of The Hague ordered Shell to reduce its operational emissions by 45% by 2030 (compared with 2019 levels) and to make a 'significant best-efforts obligation' to reduce CO_2

[114] See, e.g., *Milieudefensie et al. v. Royal Dutch Shell*.
[115] App no 53600/20 Verein Klimaseniorinnen Schweiz v Switzerland (ECtHR, pending).
[116] *Pabai Pabai & Anor v. Commonwealth of Australia*, statement of claim available at: https://fedcourt.gov.au/__data/assets/pdf_file/0003/96609/2021.10.26-Statement-of-Claim.pdf Accessed 21.08.2022.

emissions produced by the products (including oil and gas) of its subsidiaries worldwide by the same amount. In reaching this ground-breaking judgement, the court concluded that 'every emission of CO_2 and other greenhouse gases, anywhere in the world and caused in whatever manner, contributes to' 'environmental damage and imminent environmental damage' suffered by claimants in the Netherlands.[117] The scientific bases for climate change attribution and projections is closely related, including in the models used. The recognition by courts that scientific evidence of this type can be used to demonstrate defendants' contributions to specific impacts may also indicate the potential of claims based on attribution-science evidence.

Similarly, in *Gloucester Resources v. Minister for Planning*, the New South Wales Land and Environment Court held that 'there is a causal link between the … cumulative GHG emissions [of an individual coal mine] and climate change and its consequences… In this way, the Project is likely to have indirect impacts on the environment, including the climate system, the oceanic and terrestrial environment, and people'.[118] Although cases seeking compensation for climate-related impacts have not yet advanced to a point where causation has been established,[119] courts have begun to accept that even relatively small contributions to emissions can constitute breaches of duties of care. While such findings may be subject to more relaxed standards of proof than causal claims in suits seeking financial compensation for the impacts of emissions, it may bode well for future compensation claims too.

6. CONCLUSION

Climate change is causing a growing burden of impacts affecting communities worldwide that will worsen with further greenhouse gas emissions. Despite the severity of these impacts, major governance gaps exist. First, action to mitigate greenhouse gas emissions lags substantially behind that required to meet the goals of the Paris Agreement and, as is being argued in growing numbers of climate lawsuits, human rights obligations.[120] Second, the present-day impacts of climate change are already substantial yet no mechanism exists to compensate affected communities for impacts incurred. Climate science can provide a key source of

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[117] Milieudefensie v Royal Dutch Shell [2021] District Court of the Hague ECLR:NL:RBDHA:2021:5339 (official translation), p. 25.

[118] *Gloucester Resources Limited v. Minister for Planning* [2019] NSWLEC 7.

[119] *Lliuya v. RWE* can be considered to be the furthest-advanced such case, with the court initiating an evidentiary phase that is ongoing at the time of writing.

[120] J. PEEL and H. OSOFSKY, 'A Rights Turn in Climate Change Litigation?' (2018) 7 *Transnational Environmental Law* 37; SETZER and HIGHAM (n 106).

evidence for the growing numbers of legal cases that aim to address these governance gaps.

Here we focused primarily on scientific evidence on climate change impacts and its use in climate liability lawsuits. This evidence has a vital role to play in establishing causal relationships between the emissions of defendants and losses suffered by claimants. Understanding the nature of attribution science evidence is essential for considering how it can be deployed in legal settings. Attribution science and climate change projections are important sources of evidence for climate lawsuits. However, the success of climate litigation will not be determined by the quality of scientific evidence provided alone. Rather, using the best available science in conjunction with effective legal argumentation and evolving societal norms that increasingly regard climate change as a pressing humanitarian crisis create conditions that facilitate successful legal claims.

While science has a major role to play in evaluating the factual basis for legal claims, the contribution of scientific evidence is contingent on how the law is applied. If causation is to be established in climate lawsuits, issues of law must still be resolved, in particular related to the causal tests that are applied by courts, which may in turn determine the feasibility of establishing legal causation.

What do past and pending cases indicate for how the prospects of using attribution science in the context of litigation on climate damages, and more generally in the context of climate change, can be improved? Given the potential of existing scientific approaches to link the emissions of individual entities with impacts experienced by others, and the growing body of legal literature indicating that scientific assessments of this type may be sufficient to establish legal causation, claimants' arguments might be strengthened through the provision of specific attribution evidence. It is of course the case that climate litigation faces a wider range of obstacles that do not pertain to issues of causation or the scientific facts introduced to establish such relationships. Nevertheless, attribution science can provide a firm basis first for establishing standing, and ultimately to support a finding of causation in the merits stage of such cases.

Improved dialogue between lawyers, judges, and scientists may address obstacles to establishing causation, with scientists made aware of key evidentiary questions to which claimants need answers. If the scientific community is alerted to litigation-relevant questions, this may stimulate research that evaluates the scientific claims made in climate lawsuits, providing a firmer evidentiary basis if arguments are indeed supported by scientific findings. In return, lawyers can be supported to understand whether causal links do exist in fact, and whether or not it is feasible to provide evidence to establish them in court. Judges can be equipped to

effectively evaluate scientific evidence introduced in cases. Such dialogue could also support scientists in understanding how to align research methods with evidentiary requirements in legal settings, for instance reflecting the differing standards of proof used in law and science.[121]

Care should be taken to ensure that the scientific evidence provided can still remain independent from parties to a case, even if it addresses a specific legally-relevant setting. With improved access to relevant scientific research, claimants will be able to ensure that cases filed concern impacts that are demonstrably attributable to climate change. Lawyers will also be aware of, and able to request evidence that can robustly evaluate causal claims. Finally, the evidence submitted to courts will clearly substantiate the alleged relationship between defendants' emissions and claimants' losses, rebutting the incorrect claims made by certain courts that scientifically attributing impacts of climate change to individual emitters is infeasible.[122]

[121] E. LLOYD and others, 'Climate Scientists Set the Bar of Proof Too High' (2021) 165 *Climatic Change* 55.
[122] STUART-SMITH and others (n 20).