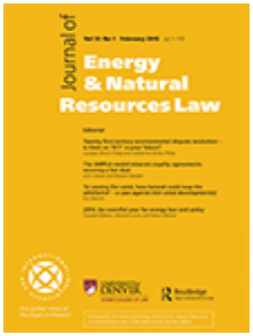

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Journal of Energy & Natural Resources Law

ISSN: 0264-6811 (Print) 2376-4538 (Online) Journal homepage: http://www.tandfonline.com/loi/rnrl20

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To cite this article: Sophie Marjanac & Lindene Patton (2018): Extreme weather event attribution science and climate change litigation: an essential step in the causal chain?, Journal of Energy & Natural Resources Law, DOI: 10.1080/02646811.2018.1451020

To link to this article: https://doi.org/10.1080/02646811.2018.1451020

Published online: 19 Apr 2018.

Journal of Energy & Natural Resources Law, 2018
https://doi.org/10.1080/02646811.2018.1451020

Extreme weather event attribution science and climate change litigation: an essential step in the causal chain?

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(*Received 15 December 2017; final version received 28 February 2018*)

The 2017 North Atlantic hurricane season caused the highest disaster-related losses ever seen in the United States, with many people asking questions about the causes and liabilities for the impacts of these kinds of events. As climate-related loss and damage mount, there is growing interest in the role of law in dealing with the complex and multi-scalar problem of climate change. This article builds on a shorter piece entitled 'Acts of God, human influence and litigation' published by the authors in *Nature Geoscience* in August 2017. It is an interdisciplinary and cross-jurisdictional analysis of the emerging science of extreme weather event attribution (which analyses the human impact on extreme weather events), and the implications this new science may have for the law, litigation and the scope of the duty of care of a range of actors. We suggest that the science of event attribution may become a driver of litigation, as it shifts understanding of what weather is expected and, relevantly for law, foreseeable. This may have an impact on the duties of government actors as well as private parties. We explain the discipline of event attribution science to lawyers, discuss some technical issues related to the use of this evidence in court and make some suggestions regarding the types of 'climate change' cases it may influence. We conclude that the first kind of litigation to emerge is most likely to arise from failures to adapt to, or to prepare for, our changing climate.

Keywords: climate change; climate change litigation; attribution science; duty of care; causation; proximate cause; foreseeability; climate change adaptation; loss and damage; climate change liability

1. Introduction

'Climate is what you expect, weather is what you get.' This common saying has been useful in expressing our understanding of the difference between climate and weather, highlighting the nature of climate sciences as the study of statistical norms derived from observed and modelled long-term patterns and trends in the earth's biosphere. This trite expression is, however, being challenged by climate change itself – which is shifting what is expected in our geological age. This affects the determination of foreseeability of climate-related risks, which may in turn translate into shifting liabilities for professionals and others in a court of law. The emerging science of extreme weather event attribution, which analyses the relationship between anthropogenic emissions to the atmosphere and specific extreme weather events – is focused on understanding the causes of that baseline shift in climate and related specific extreme weather event characteristics. Through the detailed study of the causes and factors that influence extreme weather, and by modelling the influence of

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long-term climatic forcings,[1] scientists are now able to better understand the drivers of extreme weather, and quantify the extent to which climate change shifts the goalposts of expected weather patterns.

This article will explain these scientific developments to lawyers, and explore the potential implications for the adjudication of a range of lawsuits that fall within the broad definition of 'climate change litigation'.[2] Advancements in attribution science are poised to alter significantly the legal landscape for climate-related suits. The question is not whether there will be another wave of climate-related litigation, but when it will occur and whether it will be more successful than prior efforts. This is the result of two major trends: the steady increase of extreme weather losses, and advancements in extreme weather event attribution science.

The state of attribution science will be influential in evaluating causation issues in such lawsuits and for establishing the foreseeability of weather events that were previously regarded as unpredictable. By identifying and quantifying the human influence on the extreme weather events that are increasingly causing more severe and widespread loss, damage and human suffering, this branch of science should prompt consideration of the legal implications of a world where more frequent and severe extreme weather events are not only preventable, but *demonstrably reasonably foreseeable*. The techniques developed in event attribution science can also provide valuable information about the future risks of such events to emergency managers, regional planners and policy-makers at all levels of government, and this is likely to have implications for the planning and management of building codes, land use, water, health and food management, insurance and transportation networks.

We suggest that a new focus of climate change litigation will most likely involve those individuals with alleged duties of care or specialist knowledge about climate-related risk, but who failed to share or disclose such knowledge or act in a manner consistent with such duty. Litigation of this type may become an important driver for the mitigation of greenhouse gas emissions and adaptation to the changing climate by both the public and private sectors.

2. A rapidly evolving scientific field

Climate models can now simulate with a high level of confidence the observed record of a trend of warming across the globe, which the Intergovernmental Panel on Climate Change (IPCC) attributes to human activity with high confidence.[3] The linear relationship between concentrations of atmospheric greenhouse gases and global mean surface temperature

1 An imposed perturbation of the Earth's energy balance, or referring to a forcing agent outside the climate system causing a change in the climate system. Examples include volcanic eruptions, solar variations, anthropogenic greenhouse gas emissions and land use changes.

2 Encompassing legal and quasi-legal actions that relate to the mitigation of greenhouse gas emissions, adaptation to the physical effects of climate change, and remedies for loss and damage caused by climate change. See Jacqueline Peel and Hari M. Osofsky, *Climate Change Litigation: Regulatory Pathways to Cleaner Energy* (Cambridge University Press 2015).

3 The 2014 Synthesis Report 'distils and integrates the findings of the three working group contributions to the IPCC Fifth Assessment Report – the most comprehensive assessment of climate change yet undertaken, produced by hundreds of scientists' United Nations Framework Convention on Climate Change, 'The Fifth Assessment Report of the Intergovernmental Panel on Climate Change' (2014) http://unfccc.int/science/workstreams/cooperation_with_the_ipcc/items/8732.php accessed 22 March

(GMST) was again confirmed in the IPCC's Fifth Assessment Report (AR5), published in 2014.[4] Owing to the relationship between atmospheric greenhouse gas concentrations and GMST, this measurement has been used as a proxy for the extent of global warming in international climate change law. In 2012, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) formally adopted the target of limiting greenhouse gas concentrations such that the GMST would rise no more than two degrees above pre-industrial levels.[5] Article 2 of the Paris Agreement commits signatories to:

> [h]old […] the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

Scientists have noted that the two-degree target was a political consensus formulated after an analysis of the trade-off between expense and risks,[6] and does not necessarily reflect a 'safe' upper limit under which no harmful effects will occur.[7]

Although GMST is a useful metric when analysing global warming,[8] it does not reflect the way in which people and societies will experience climate change, as the

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2018. The Synthesis Report contains the following key findings:

'1. Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gasses are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.'

'1.1 Warming of the climate system is unequivocal, and since the 1950s, many of the changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.'

'1.2 Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.' IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland (AR5 Synthesis Report), 40, 44.

The process of the IPCC is based on a consensus-driven evaluation of underlying evidence and agreement among all scientific studies published during the assessment period. The IPCC uses specific terminology to assess and rank the robustness of evidence and agreement, as well as levels of confidence in particular findings; a summary of these terms is found in on page 37 of the Synthesis Report and in Michael D Mastrandrea and others, 'Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties' (IPCC 2010).

4 AR5 Synthesis Report, IPCC (2014) see n 3 at 63.

5 'Report of the Conference of the Parties on its Eighteenth Session, Held in Doha from 26 November to 8 December 2012 – Addendum – Part Two: Action Taken by the Conference of the Parties at its Eighteenth Session' UN Doc FCCC/CP/2012/8/Add.1 (UNFCCC 2012).

6 At the G8 conference in Italy in 2009, heads of state and government first acknowledged the importance of ensuring that global warming does not exceed two degrees above pre-industrial levels, upon receipt of the scientific advice that such warming would lead to potentially irreversible and uncontrollable consequences. See German Advisory Group on Global Change (WBGU), *Solving the Climate Dilemma: The Budget Approach* (Special Report, WBGU 2009) www.wbgu.de/en/special-reports/sr-2009-budget-approach accessed 31 January 2018.

7 Reto Knutti and others, 'A Scientific Critique of the Two-Degree Climate Change Target' (2016) 9 Nature Geoscience 13.

8 For a live graph tracking human-induced global warming relative to the mid-19th century see Christopher Leedham and Myles Allen 'Globalwarmingindex.org' (2018) http://globalwarmingindex.org accessed 31 January 2018.

impacts of a two-degree rise in GMST vary significantly in the different regions of the globe, and could mean an increase in average temperature of up to six degrees in some areas.[9] Before the advent of extreme weather event attribution science, specific analysis and quantification of the impact of global anthropogenic forcings on regional weather patterns were thought to be impossible. Most predictions to date have been quite general (such as 'increased incidences of heatwaves in South-Eastern Australia'), and did not include the kind of specific predictive information about the increased likelihood of local and regional events that may assist local officials to make specific preparations (such as 'a threefold increase in the likelihood of seven consecutive nights with temperatures above 30 degrees in western Sydney').

Extreme weather event attribution (which we refer to simply as 'event attribution') is the science that seeks to determine the extent to which anthropogenic climate change has altered the probability[10] or magnitude[11] of the particular weather event or class of weather events that are the subject of study. In other words, attribution science studies the way people experience climate change. The technical definition of attribution is 'the process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence'.[12] Accordingly, both weather-related events (such as short-term heavy precipitation) or climate-related events (such as a high mean summer temperature) in a particular region could be the subject of an attribution study.[13]

The first event attribution study was published in 2004, and analysed the link between anthropogenic climate change and the 2003 European heatwave, an extreme event that resulted in widespread heat-related deaths across Western Europe.[14] Event attribution is an attempt by scientists to respond to the public and media interest in the causes of extreme weather events, the impact of which is often most pronounced in the event's immediate aftermath. In doing so, scientists have cautioned that a simplistic attribution of any event to anthropogenic climate change in the absence of scientific analysis or consensus is as misguided as the claim that it is not possible to link individual extreme events with climate change resulting from human greenhouse gas emissions.[15]

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9 Sonia I Seneviratne and others, 'Allowable CO2 Emissions Based on Regional and Impact-Related Climate Targets' (2016) 529 Nature 477, cited in University of New South Wales, 'How a 2°C Rise Means Even Higher Temperatures Where We Live: Land Based Temperatures Rise Much Faster than Global Average Temperatures' (*ScienceDaily*, 20 January 2016) www.sciencedaily.com/releases/2016/01/160120141531.htm accessed 30 January 2018.

10 The frequency or likelihood of a defined event. We note that, for certain events, such as heavy precipitation events, the total number (frequency) could remain the same or actually decrease in the future, while events relating to heat, including droughts, are increasing in many regions.

11 The severity or strength of a defined event.

12 Gabriele C. C Hegerl and others, 'Good Practice Guidance Paper on Detection and Attribution Related to Anthropogenic Climate Change' in Thomas Stocker and others (eds), *Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Detection and Attribution of Anthropogenic Climate Change* (IPCC Working Group I Technical Support Unit, University of Bern 2010) 2.

13 Peter A. Stott and others, 'Attribution of Extreme Weather and Climate-Related Events' (2016) 7 WIREs Clim Change 23.

14 Peter A Stott, DA Stone and MR Allen, 'Human Contribution to the European Heatwave of 2003' (2004) 432 Nature 610. A more recent study quantified the deaths resulting from this heatwave and attributed a proportion to anthropogenic influence: Daniel Mitchell and others, 'Attributing Human Mortality During Extreme Heat Waves to Anthropogenic Climate Change' (2016) 11 Environ Res Lett, Article 074006 https://doi.org/10.1088/1748-9326/11/7/074006 accessed 22 March 2018.

15 See n 13 above at 2.

In 2012, the American Meteorological Society commenced publication of a special annual supplement to its Bulletin, compiling articles focused on the attribution of specific extreme weather events over the previous year.[16] The volume of studies undertaken each year continues to increase steadily, with methodologies also improving. *Explaining Extreme Events of 2015 from a Climate Perspective* (2015 BAMS Report), published in December 2016 noted that many studies detected with high confidence the contribution made by climate change to certain extreme weather events.[17]

All studies of heat-related events included in the 2015 BAMS Report were found to have been made more intense or likely due to human-induced climate change, with the editors also noting the markedly improved ability of scientists to differentiate between human and natural drivers of temperature extremes (such as the El Niño effect).[18] Most studies included in *Explaining Extreme Events of 2016 from a Climate Perspective* (2016 BAMS Report), published in January 2018,[19] also found a pronounced climate signal in heat-related events. Notably, and for the first time, it also included a number of studies in which the authors concluded that the event in question would not have been possible in the counterfactual world, that is, the world without human influence. These events included the global record heat of 2016, an oceanic heatwave off the coast of Alaska and the heatwave across Asia, and show that human influence is pushing weather patterns beyond the bounds of what is possible with natural variability alone. Recent studies have also shown that increased wildfire risk has been causally linked to anthropogenic forcings.[20] Furthermore, changes in climatic impacts are now sufficiently foreseeable to allow modelling of specific health impacts from extreme weather events,[21] as well as overall economic damages expected from climate change in the United States.[22] The 2016 BAMS Report notes that there is a growing interest in 'impact attribution' studies, being those that 'investigate whether climate change's influence on the extreme event can subsequently be directly tied to a change in risk of the socio-economic or

16 These annual supplements to the Bulletin of the American Meteorological Society (BAMS) are available at www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective accessed 22 March 2018.

17 Stephanie C. Herring and others (eds), 'Explaining Extreme Events of 2015 from a Climate Perspective' (2016) 97(12) Bull Amer Meteor Soc S1–S145 www.ametsoc.net/eee/2015/2015_bams_eee_low_res.pdf. accessed 22 March 2018.

18 See Stephanie C. Herring and others (n 17) at S3.

19 Stephanie C. Herring and others (eds), 'Explaining Extreme Events of 2016 from a Climate Perspective' (2018) 99(1) Bull Amer Meteor Soc S1–S157 http://www.ametsoc.net/eee/2016/2016_bams_eee_low_res.pdf accessed 22 March 2018.

20 Megan C Kirchmeier-Young and others, 'Attributing Extreme Fire Risk in Western Canada to Human Emissions' (2017) 144 Climatic Change 365.

21 In a 2016 study, Daniel Mitchell and others (n 14) used epidemiological and other statistical techniques to link heat-related mortality to the 2003 Paris and London heatwave. They find that human-caused climate change increased the risk of heat-related mortality in central Paris by ~70 per cent and directly contributed to approximately 506 (±51) deaths. The 2015 BAMS Report (n 17) notes the importance of this study, stating (at S2) that:

> While the numbers for this heat wave are noteworthy, especially for Paris, the paper makes a larger contribution than just its analysis of the 2003 event. It lays out a methodology for linking the role of climate change on an extreme heat event and, subsequently, the impacts of that event on human health.

22 Solomon Hsiang and others, 'Estimating Economic Damage from Climate Change in the United States' (2017) 356 Science 1362.

environmental impacts', with several papers addressing these matters, including studies of the Great Barrier Reef bleaching, living marine resources in the Pacific, and ecosystem productivity on the Iberian Peninsula.[23] The significant number and severity of extreme weather events during 2017 – from wildfires, to droughts, to heavy rains and hurricanes – have resulted in a steadily increasing demand for event attribution studies,[24] as well as predictive regional studies.

2.1. *Methodology and framing*

Weather extremes occur naturally and by definition, infrequently. Given the relatively short duration of observational weather records,[25] as compared to the overall time of human life on Earth, as well as the limited geographic coverage of reliable temperature and rainfall records,[26] it is difficult, but increasingly possible with scientific, computational and other technological advances, to detect systemic changes in the occurrence of extreme weather events. Event attribution involves consideration of a host of possible natural and anthropogenic factors (including but not limited to large-scale circulation,[27] regional circulation, internal modes of climate variability, anthropogenic greenhouse gas emissions, aerosol effects[28] and dynamic and thermodynamic factors) that combine to produce the specific conditions of an event.[29] Furthermore, the Earth's atmosphere and natural systems are interdependent and interconnected in ways that are, in some cases, only partially understood.

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23 Stephanie C. Herring and others (n 19) at Sii.

24 Interest in attribution science was extremely high after Hurricane Harvey hit Texas in September 2017. The team behind the website, World Weather Attribution, completed a study of the event in December 2017 World Weather Attribution, Hurricane Harvey August 2017' https://wwa.climatecentral.org/analyses/hurricane-harvey-august-2017 accessed 31 January 2018.

25 Global temperatures records vary depending upon the area covered. Regional and global data is available back to 1880. See Combined Land-Surface Air and Sea-Surface Water Temperature Anomalies (Land-Ocean Temperature Index, LOTI):

- Global-mean monthly, seasonal, and annual means, 1880-present, updated through most recent month: *TXT, CSV*
- Northern Hemisphere-mean monthly, seasonal, and annual means, 1880-present, updated through most recent month: *TXT, CSV*
- Southern Hemisphere-mean monthly, seasonal, and annual means, 1880-present, updated through most recent month: *TXT, CSV*
- Zonal annual means, 1880-present, updated through most recent complete year: *TXT, CSV*

But measures with greater resolution vary in their availability from 1951 and later. See https://data.giss.nasa.gov/gistemp which documents how technology changes affect resolution data set quality from 1950 to the present with consistent improvements.

26 As noted in n 25 above, geographic coverage and specificity/resolution have been steadily improving since the 1950s with the advent of space-enabled and other earth observation technologies. However, large areas of the globe are not subject to reliable weather observations.

27 Being the large-scale movement of either air (atmospheric circulation) or water (ocean circulation) and the means by which thermal energy is redistributed on the surface of the Earth.

28 Aerosols are microscopic liquid or solid particles that enter the atmosphere through natural and man-made processes. They include dust sulphate particles and black carbon, and can have both warming and cooling effects in the atmosphere. The AR5 Synthesis Report reports the scientific consensus that overall, they have a cooling effect on the earth's climate, which is offset by the warming effect of greenhouse gases: see diagram on p 48 of the Synthesis Report (n 3).

29 National Academies of Sciences, Engineering, and Medicine, *Attribution of Extreme Weather Events in the Context of Climate Change* (The National Academies Press 2016) (NAS Report) 1.

In 2016, the National Academy of Sciences (NAS) produced what the 2015 BAMS Report described as the 'most comprehensive look at the state of event attribution science, including how the framing of attribution questions impacts the results'.[30] The NAS Report validated a number of the key methodologies used in event attribution studies, and provided an independent analysis from outside the event attribution community, confirming that the basic scientific and statistical methodologies used have the potential to produce robust conclusions.[31]

Event attribution relies on the existing and developed science and technology of detection and attribution of long-term changes in the characteristics of the climate, and the models developed to simulate these processes. Although there are several approaches to event attribution, the primary approach used in detection and attribution research is to compare the changes in the observable record over time with climate models to assess whether atmospheric greenhouse gas concentrations can be correlated with the changing trends in the observation records. The 'real world', defined through observations and models, is compared to the 'counterfactual world' modelled without human forcings (greenhouse gases and aerosols) allowing isolation and analysis of the influence of anthropogenic factors. Although the various methodologies are continually improving, the basic comparison between the real and counterfactual worlds is an accepted method of determining probabilistic causation in a number of scientific disciplines including epidemiology.[32]

Crucially, the framing of the question posed by a particular event attribution study (including the definition of the event), and the methodology used, including the climate models chosen, can significantly influence its conclusions. At the time of writing, the results of event attribution studies often remain subject to significant uncertainty, particularly for events that are not directly temperature-related due to data gaps or gaps in knowledge about the causal links between anthropogenic forcings and more complex weather patterns.[33] Furthermore, if the event being studied is also influenced by human activity such as forest management (in the case of wildfires), then the results of an attribution study considering the influence of greenhouse gas emissions will be more complex.[34]

Because different climate models vary in their ability to simulate specific weather patterns, the choice of model and methodology will influence the robustness of the findings. The robustness of the findings of attribution studies will depend on what have been termed the 'three pillars' of attribution science: (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.[35] Accordingly, studies will be more accurate where:

30 Stephanie C. Herring and others (n 17) S1.
31 NAS Report (n 29) 12.
32 NAS Report (n 29) 29–30. Further discussion below.
33 For example, the NAS Report (n 29) 7 notes that

> [t]he frequencies and intensities of tropical cyclones and severe convective storms are related to large-scale climate parameters whose relationships to climate are understood to varying degrees but, in general, are more complex and less direct than are changes in either temperature or water vapor alone.

34 See NAS Report (n 29) 7.
35 See Stephanie C. Herring and others (n 17) S1.

- there are long-term, reliable, observational records of the event to place it in an appropriate historical context, such as heat events where the temperature observational records are reasonably long;
- the event is simulated accurately in climate models;[36] and
- the event is not one that is significantly affected by non-climatic factors, such as geography, resource management actions or built infrastructure (for example, floods, convective storms or wildfires in some circumstances).

Conclusions are sensitive to the choices and assumptions made in the selection of methodology, the framing of the questions posed,[37] the selection and definition of the event, and the selection of statistical tools applied to quantify uncertainty.[38] This sensitivity is not unique to attribution science related modelling, and is also found in modelling tools relied on for decades by industry, government and society in general for analyses and forecasting related to matters such as routine weather forecasting, natural catastrophe modelling and epidemiologic modelling. Stronger attribution science studies explain the assumptions of methodology and statistical analyses clearly and test their conclusions against a number of alternative scenarios.[39]

2.2. *Understanding and interpreting results*

2.2.1. Probabilistic findings

Similar to methodologies regularly applied in epidemiological studies of the causes of disease, event attribution science frequently uses probabilistic methods to identify the influence of anthropogenic factors on extreme weather events. Scientists previously rejected the notion that deterministic attribution of results[40] was possible, although this position has recently changed as noted above, demonstrating the rapid progress of this field.

Although three studies in the 2016 BAMS Report found that the heat events studied did not occur in the modelled pre-industrial climate, when addressing climatic event attribution to anthropogenic greenhouse gas emissions, we are almost always dealing

36 Events that are most adequately simulated in climate models are those where there is an understood and robustly simulated physical mechanism that relates a given class of extreme events to long-term anthropogenic climate changes such as global-scale temperature increase or increases in water content of a warmer atmosphere. Also, the simpler the model, with fewer driving variables, the easier to verify. This again is why it is easiest to confirm attribution linkages to severe heat events.

37 For example, the difference in results of studies considering the magnitude and frequency of the same event could produce different conclusions that can risk misinterpretation. The oft-cited example of this, cited as a warning to researchers regarding the importance of asking the right question in attribution studies, is the differing results obtained by two studies undertaken in relation to the 2010 Russian heatwave. The studies appeared to produce conflicting conclusions in relation to human influence on the event, but these results were entirely explainable by the different framing of the attribution question: see NAS Report (n 29) 30–32.

38 See NAS Report (n 29) 4–13.

39 See NAS Report (n 29) 12, noting that 'unambiguous interpretation of an event attribution study is possible only when the assumptions and choices that were made in conducting the study are clearly stated and uncertainties are carefully estimated'.

40 That is, compliant with the strict definition of necessary causation, which can be equated with the legal test of 'but for' causation, meaning that the event could never have occurred without the presence of the causal factor.

with what US lawyers call 'proximate cause' in the toxic tort context.[41] As such, the scientific inquiry focuses not on whether the event would or would not have occurred without human-caused greenhouse gas emissions, but rather on the question of how that influence has changed the characteristics of the event. Scientists resist the idea that the simple question 'Was event X caused by climate change?' can be answered, and instead suggest that a more helpful question to ask is 'How has human activity changed the likelihood of this event occurring or its magnitude?'.

Accordingly, strictly deterministic causation in attribution science is only possible where the climate has changed so much that an extreme event is no longer extreme relative to the baseline because the baseline has shifted with climate change. This of course becomes a somewhat existential discussion – about whether the event is really 'extreme' – and can easily cause professional and lay people to lose focus on the core issue, that is, the manner in which human greenhouse gas emissions are changing atmospheric events in a manner that causes increased risk of harm and damage, and even death. While recent studies have shown that a baseline shift is occurring in respect of certain heat-related events, this is not yet typical. Event attribution is therefore most frequently the study of changing probabilities rather than a deterministic yes or no expression of causality.[42] Importantly for scientists, this means that the predictability of extreme weather events will improve as we come to better understand the drivers of extreme weather events in regional areas. Importantly for governments, built environment professionals, companies and their lawyers, this means that the *foreseeability* of specific kinds of extreme events will be increasingly enhanced with this improved understanding.[43]

Results are now more frequently reported as an increase in risk of an event, using the risk ratio, or RR, which is an expression of the factual probability (p1) compared to

41 Proximate cause is a concept used by US courts to place limits on the scope of liability for the causal analysis in a negligence claim. The analyses of probable causation typically address probabilistic estimates of the relationship between a behaviour which breaches a duty and the claimed injury or damages where the causal analysis does not satisfy the 'but for' test (necessary causation) but is still sufficiently reasonably foreseeable to have led to the claimant's injuries. (See generally Restatatement (Third) of Torts § 29 (am. Law Inst. 2010) 3d of Torts: Liability for Physical and Emotional Harm, s 29 (3rd 2010).) Quoting directly from the Restatement –

> To apply this rule requires consideration, at an appropriate level of generality, see Comment i, of: (a) the risks that made the actor's conduct tortious, and (b) whether the harm for which recovery is sought was a result of any of those risks. Risk is explained in § 3, Comment e, as consisting of harm occurring with some probability. The magnitude of the risk is the severity of the harm discounted by the probability that it will occur. For purposes of negligence, which requires foreseeability, risk is evaluated by reference to the foreseeable (if indefinite) probability of harm of a foreseeable severity. If a strict-liability claim does not require foreseeability, the concept of risk can be determined by examining the severity and probability in retrospect. See Comment j.

Restat 3d of Torts: Liability for Physical and Emotional Harm, s 29 (3rd 2010).

42 In the scientific sense, used here to distinguish from the legal concept of causation.

43 This is because the shifts in expected return times for specific events are calculated in order to identify the human influence in the event under consideration. The NAS Report (n 29 at xix) states that

> 'a return time … is a commonly used metric of probability; for example, a 100-year return time means that in any given year, there is a 1-in-100 chance of the threshold being reached. If the climate were not changing, return time could also be interpreted as average time between events, but it should not be interpreted as the time that will pass before an event occurs again.'

the counterfactual probability (p0RR = (p1/p0)).[44] This is analogous to how epidemiological results are presented in studies of risks to health.[45]

2.2.2. Uncertainty

Further complexities arise from the variety of ways that scientists (who are often working with different data sources and models) describe the degree of certainty about their findings. In law, uncertainty is relevant to the applicable standard of proof (for example, 'more likely than not' in civil cases, and 'beyond reasonable doubt' in criminal cases), to which we will shortly turn.

Sampling uncertainty is inherent in all scientific study and arises from any attempt to quantify the intensity and frequency of independent events using data sets of limited size from either observations or simulations in model runs. Uncertainty can be reduced by having good observational data or, theoretically, through the repetition of the simulations across multiple model runs, or by sensitivity testing with slightly different event framings.[46] Quantifying this uncertainty can be done using well-established statistical techniques, such as sensitivity testing, the confidence interval or Z-scores.[47]

Different event attribution studies quantify uncertainty differently, just as they report their results differently. However, it should be noted that sampling uncertainty alone (ie, through the reporting of a confidence interval) does not, in and of itself, indicate anything about the relationship between cause and effect. It is simply a method of reporting results in light of the probability that one could see similar results by chance. The confidence interval indicates that the majority of modelled results fit within a certain range, and is a statistical concept used by scientists of all disciplines to indicate that their results are based on incomplete data sets.

Structural or modelling uncertainty arises from the fact that the quality of the results necessarily depends on the representativeness of the chosen model in simulating the event types under analysis. In other words, like face-recognition software, the ability of the software model to recognise a 'face' (ie, unique event) is dependent on how well the model represents the identifying characteristics of the 'face'. Close correlation of modelled results with observations, where possible, helps to build confidence in the model's capacity to simulate and predict real conditions.[48] Performing a sensitivity

44 Some studies use the fraction of attributable risk (FAR) ratio rather than the RR, which expresses the factual probability (p1) compared to the counterfactual probability (p0) as a fraction. FAR = 1 – (p0/p1). This method of describing results is becoming less common in attribution studies.

45 See discussion in NAS Report (n 29) at 34, noting that this method of presenting results is preferred in epidemiology.

46 See NAS Report (n 29) 12–13.

47 This is a standard statistical technique. Z-scores indicate how many standard deviations a value is from a mean of a distribution and give the user an understanding of how widely the results (model outputs) vary relative to the mean output number. In some cases, widely varying outputs can result in situations where many outputs are both below the mean and below zero, which can call into question the validity of a simulated output.

48 Where the model does not simulate an event well (and there are well-recognised deficiencies in all climate models, for example, their ability to simulate cloud behaviour and precipitation, particularly over land) the results of an attribution study relying on that simulation are likely to be more uncertain. Some studies may require 'bias correction' where it is known that models do not simulate a particular type of event well, and this should be clearly explained in the study. Other types of events may not be amenable to study, simply because of the fact that the current models do not simulate these events well,

analysis, by using multiple models applied to test for the same process being studied, can help reduce this kind of uncertainty.[49] In other words, you can compare the model outputs, and where the ranges overlap, you can have more confidence, and less uncertainty, about the model outputs.

Many attribution studies currently do not express or explain their uncertainty estimates so that they can be understood by lay readers, nor do they use standardised techniques for their calculation. This largely occurs because the statistical methodologies used are extremely difficult to explain – as is also evident in this article. This sometimes makes it difficult for stakeholders to evaluate the reliability or credibility of uncertainty statements in those attribution studies. In order to be useful for a range of stakeholders and end-users of this highly relevant science, attribution studies should transparently explain the issues that may lead to uncertainty of result, and clearly quantify this so that model outputs can be compared on both a direct and relative basis. We agree with the US National Academy of Sciences, which concludes that attributes of a successful operational event attribution system would include 'clear communication of key messages to stakeholders about the methods and framing choices as well as the uncertainties and probabilities'.[50]

3. Application to climate change litigation

As is often noted by policy-makers and lawyers, climate change is the ultimate 'wicked' problem, due to its trans-boundary causes and effects, the complexity and multi-scalar[51] nature of mitigation efforts, its slow-moving latent nature, and the likely scale and scope of resultant damages.[52] Not only are individuals throughout the developed and developing world exposed to the physical impacts of a changing physical environment, but cities, states, companies, investors[53] and the financial system as a whole[54] are highly exposed to the economic implications of higher temperatures and more frequent and intense weather events. Furthermore, as noted by the International Bar Association

such as tropical storms or cyclonic cells. Temperature extremes can be addressed with the highest degree of confidence using the Coupled Model Intercomparison Project Phase 5 (CMIP5) class models, although there may be some challenges where land mass heat provides feedback loops.

49 See NAS Report (n 29) 62.

50 See NAS Report (n 29) 16.

51 In this context, we refer to the multiple scales of emissions reductions required to influence global atmospheric greenhouse gas concentrations including at global, regional, national and local levels adjusted temporally and spatially.

52 Jacqueline Peel, 'Issues in Climate Change Litigation' (2011) 5 Carbon and Climate Law Review 15.

53 Mercer, 'Investing in a Time of Climate Change' (2015) www.mercer.com/our-thinking/investing-in-a-time-of-climate-change.html.

54 Prudential Regulation Authority, 'The Impact of Climate Change on the UK Insurance Sector: A Climate Change Adaptation Report by the Prudential Regulation Authority' (Bank of England, September 2015) www.bankofengland.co.uk/pra/Documents/supervision/activities/pradefra0915.pdf accessed 22 March 2018; in Australia, see Geoff Summerhayes, 'Australia's new horizon: Climate change challenges and prudential risk' (Australian Prudential Regulation Authority, 17 February 2017) www.apra.gov.au/Speeches/Pages/Australias-new-horizon.aspx accessed 22 March 2018. Timothy Lane, 'Thermometer Rising - Climate change and Canada's Economic Future' (Bank of Canada 2 March 2017) www.bankofcanada.ca/2017/03/thermometer-rising-climate-change-canada-economic-future accessed 22 March 2018; and French Treasury, 'Assessing Climate change-related risks in the banking sector: synthesis of the project report submitted for public consultation with regard to Article 173 (V) of the 2015 French Energy Transition Act' (French Treasury, 2017) www.tresor.economie.gouv.fr/File/433465 accessed 22 March 2018.

(IBA) Climate Change Justice and Human Rights Task Force, climate change 'disproportionately strikes those who have contributed least to it and who are also, for a variety of reasons, least well-placed to respond'.[55] Accordingly, climate change raises fundamental issues of equity and justice.

Attempts to address climate change through international cooperation remain challenging and contested, despite the entry into force of the Paris Agreement in November 2016.[56] Citizens and those concerned with the current and imminent scale of loss and damages associated with climate change are increasingly turning to the courts for remedy. Recognising gaps in the existing frameworks, the IBA Task Force acknowledged that courts are likely to be called upon to adjudicate matters related to climate change. In order to assist the courts in dealing with these complex matters and to facilitate access to justice for persons affected by climate change, the IBA Task Force recommended that a Model Statute on Legal Remedies for Climate Change be drafted, addressing both substantive and procedural obstacles.[57]

The sheer and ever-increasing scale of the climate resilience gap[58] is also likely to provide impetus for loss-shifting litigation between private parties, in a range of traditional and non-traditional areas including professional liability, negligence, premises liability, insurance, contract law, sovereign liability and securities laws and rules regulating the listing, sale and purchase of company stocks.[59]

Climate change litigation has been brought under a range of legal theories, most frequently under administrative law and environmental statutes.[60] In this article we will first discuss some general matters relating to the use of probabilistic event attribution science in court, and some issues relevant to liability for greenhouse gas emissions. We then turn our focus to common law remedies including tort-based litigation

55 International Bar Association Climate Change Justice and Human Rights Task Force, *Achieving Justice and Human Rights in an Era of Climate Disruption* (IBA 2014) 34 www.ibanet.org/PresidentialTaskForceClimateChangeJustice2014Report.aspx accessed 22 March 2018.

56 United Nations Climate Change, 'Paris Agreement - Status of Ratification' (2014) http://unfccc.int/paris_agreement/items/9444.php accessed 22 March 2018.

57 IBA Task Force (n 55) 27. The IBA Task Force's Report recommended that the Model Statute address a number of issues relevant to the resolution of climate change litigation, including actionable rights affected by climate change, standing, causation, the development of methods for awarding remedies (including uniform methods to apportion damages) and guidelines on costs and jurisdiction, 11.

58 The climate resilience gap is the divergence between the level of protection afforded to assets, people and communities, and the level of protection that is required to reduce climate-related losses to ensure resilience. See Lindene Patton and Felicia Barnes, 'Science and the Law: An Imperfect History Continues – Development of Attribution Science for Climate Change Related Impacts to Compensation and Reparations' in Bridget M Hutter (ed), *Risk, Resilience, Inequality and Environmental Law* (Edward Elgar 2017) https://doi.org/10.4337/9781785363801.00017. The 2017 North Atlantic hurricane season provided the perfect example of the extreme weather event resilience gap – with damage estimates ranging from US$100bn to US$300bn for US-based losses alone and utter devastation in the Caribbean islands much of which is simply uninsured. Brian K Sullivan, 'The Most Expensive U.S. Hurricane Season Ever: By the Numbers' Bloomberg, 27 November 2017 www.bloomberg.com/news/articles/2017-11-26/the-most-expensive-u-s-hurricane-season-ever-by-the-numbers accessed 22 March 2018.

59 Task Force on Climate-related Financial Disclosures, *Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures* (June 2017) available at www.fsb-tcfd.org/publications accessed 22 March 2018. At the request of Mark Carney, Governor of the Bank of England, Michael Bloomberg chaired the TCFD's inquiry into the risks of climate change to investors, conducted in 2016–17. The Final Report was presented to the finance ministers of the G20 in July 2017.

60 See Sabin Centre for Climate Change Law 'Climate Change Litigation Databases' (2018) http://climatecasechart.com accessed 30 January 2018.

against government officials, professionals, companies, and their directors and officers who may have legal duties to adapt to, warn of and/or take other action in response to a changing climate. In the US, where much environmental liability is based on case law, we suggest that courts will increasingly be asked to adjudicate on these matters, with an emphasis on negligence claims and claims based on other special duty common and statutory law based theorem.

Most tort-based climate change litigation[61] to date has occurred in the US,[62] where it has faced stumbling blocks similar to those encountered by earlier mass tort litigation efforts that are heavily science-based. These prior litigation efforts, including those involving tobacco, asbestos, pharmaceuticals and other toxic substances, all faced causation issues and potential defences to insurance coverage. Climate change has additional hurdles, primarily in relation to establishing a duty of care, as well as standing and justiciability issues, which led to the early dismissal of the majority of tort-based claims against major emitters and producers of greenhouse gases.[63] Despite the set-backs experienced by these 'first-wave' tort claims, the flexibility of the common law in dealing with new challenges should not be underestimated.[64]

Since 2015, across various jurisdictions, there has been a significant increase in the number and scope of claims falling within the broad definition of 'climate change litigation'.[65] In 2015, a Dutch non-governmental organisation (NGO) called the Urgenda Foundation successfully obtained a court order that required the Dutch government to increase its national emissions reduction target to accord with the IPCC's recommendations for developed countries.[66] The US is currently the subject of a claim by a group of young people (supported by the NGO Our Children's Trust)[67] alleging infringement of substantive due process rights through governmental failure to ensure a

61 Defined broadly as litigation in which climate change arises as a relevant issue in the proceedings.

62 Michael B Gerrard and Joseph A MacDougald, 'An Introduction to Climate Change Liability Litigation and a View to the Future' (2013) 20 Connecticut Insurance Law Journal 153, 153:

> [m]ore climate change cases have been brought in the United States than in the rest of the world combined, and the United States stands alone in seeing significant litigation that seeks to hold greenhouse gas (GHG) emitters liable for the harms caused by climate change.

63 Such as, for example, *Kivalina v ExxonMobil*, 663 FSupp 2d 863 (ND Cal 20 September 2009); *Native Village of Kivalina v ExxonMobil Corp*, 696 F 3d 849, 854 (9th Cir 2012). See also *California v General Motors Corporation, et al*, 2007 WL 272871 (ND Cal, 17 September 2007). See also *Korsinsky v EPA*, No 05 Civ 859 (NRB), where it was held that a public nuisance claim against six automakers for contributing to climate change was non-justiciable.

64 Martin Olszynski, Sharon Mascher and Meinhard Doelle, 'From Smokes to Smokestacks: Lessons from Tobacco for the Future of Climate Change Liability' (April 24, 2017) Geo Envtl L Rev, 2017 Available at SSRN: https://ssrn.com/abstract=2957921 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2957921 accessed 22 March 2018.

65 See discussion of worldwide climate litigation trends in United Nations Environment Programme, *The Status of Climate Change Litigation* (May 2017) http://columbiaclimatelaw.com/files/2017/05/Burger-Gundlach-2017-05-UN-Envt-CC-Litigation.pdf; and also Maria L. Banda and Scott Fulton, 'Litigating Climate Change in National Courts: Recent Trends and Developments in Global Climate Law' in (2-2017) 47 Environmental Law Reporter 10121.

66 *Urgenda Foundation v The State of the Netherlands*, C/09/456689/HA ZA 13-1396, Judgment of 24 June 2015; Jolene Lin, 'The First Successful Climate Negligence Case: A Comment on Urgenda Foundation v. The State of the Netherlands' (University of Hong Kong, Faculty of Law, Research Paper No 2015/021); Roger Cox, 'A Climate Change Litigation Precedent: Urgenda Foundation v The State of the Netherlands' (CIGI Papers, No. 79, November 2015) www.cigionline.org/sites/default/files/cigi_paper_79web.pdf accessed 22 March 2018.

67 www.ourchildrenstrust.org.

stable and functioning climate system.[68] Litigation in Australia over new coal mines continues to be a hotly contested issue.[69] Recently, tort-based litigation against the German utility RWE has been permitted to proceed to trial,[70] and the City of New York as well as several California local governments have recently brought suits in public nuisance and other torts against producers of fossil fuels.[71] We make some comments relevant to this class of claim in Section 3, due to the significant interest in cases that seek to hold the largest emitters and producers of fossil fuels accountable for loss and damage arising from climate change. In Section 4 we focus on litigation arising from failures to manage risk or adapt to extreme weather events as we consider that claims in this class are the most likely to succeed in the near future. It must be emphasised that event attribution science can identify the extent to which all human greenhouse gas (GHG) emissions since the beginning of the industrial revolution have contributed to an extreme weather event, but that it does not respond to the question of 'who' caused those greenhouse gases to be emitted into the atmosphere. In other words, fingerprinting of GHG molecules has not yet occurred and – even if it does – a framework to deal with the fungible nature of the contribution to the atmospheric conditions would be required in a manner similar to the legal analyses we discuss below. To date only a few studies have quantified the relative contributions of atmospheric levels of anthropogenic GHGs by both private[72] and public (nation-state)[73] actors to attempt to resolve this question. Nevertheless, event attribution science opens the door to establishing, for the first time, evidence of specific and quantifiable loss and damage arising out of atmospheric levels of anthropogenic GHGs that can be

68 Litigation is currently ongoing before the US District Court of Oregon against the US Federal Government under the constitution and public trust doctrine: see *Juliana v United States*, No 6:15-CV-01517-TC, 2016 WL6661146 (10 November 2016). The case is being brought by a group of youth plaintiffs who allege, inter alia, that the US is violating their fundamental rights protected under the US Constitution by failing to regulate greenhouse gas emissions so as to preserve a safe and habitable climatic system. Procedural wrangling to date in this precedent-setting case has been significant, including a filing of a petition for a writ of mandamus by the defendant US Government in the Ninth Circuit Court of Appeals, seeking a determination that the Oregon District Court had over-stepped its authority in adjudicating the case. The US government's writ was dismissed on 7 March 2018 in *In re United States of America* No. 17-71692 (9th Cir. March 7, 2018).

69 Environmental Law Australia, 'Carmichael Coal Mine Cases in the Land Court & Supreme Court of Qld' http://envlaw.com.au/carmichael-coal-mine-case accessed 22 March 2018.

70 Lliuya ./. RWE AG (Az 5 U 15/17 OLG Hamm).

71 Chris Mooney, 'New York City sues Shell, ExxonMobil and other oil companies over climate change' (Washington Post, 10 January 2018) www.washingtonpost.com/news/energy-environment/wp/2018/01/10/new-york-city-sues-shell-exxonmobil-and-other-oil-majors-over-climate-change/?utm_term=.6d1574e98bbd accessed 22 March 2018; Sophie Marjanac, 'New Californian climate lawsuit against 'Big Oil' filed' (ClientEarth, 21 September 2017) www.clientearth.org/new-californian-climate-lawsuit-big-oil-filed accessed 22 March 2018; ClientEarth 'Carbon majors to face court over rising sea levels in California' (18 July 2017) www.clientearth.org/carbon-majors-face-court-rising-sea-levels-california accessed 22 March 2018.

72 See the work of Richard Heede, which attributes 63 per cent of global carbon dioxide equivalent emissions to the products of 90 investor-owned, state-owned, nation-state producers of oil, natural gas, coal and cement from as early as 1854 to 2010. Richard Heede, 'Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010' (2014) 122 Climatic Change 229, and the latest work attributing temperature rise to each of these actors: B. Ekwurzel and others, 'The Rise in Global Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers' (2017) 144 Climatic Change 579.

73 Friederike EL Otto and others, 'Assigning Historic Responsibility for Extreme Weather Events' (2017) 7 Nature Climate Change 757.

linked to specific regions or individuals, and is therefore likely to be relevant to damages claims against large emitters.

3.1. *Evidentiary issues*

Courts have established processes for receiving expert testimony on various technical scientific topics (although the manner in which they engage with such evidence has been the subject of criticism).[74] Various rules of evidence to determine the veracity and credibility of expert testimony can be employed to assess the reliability of event attribution studies, just as with any other scientific field. In the US, England and Wales, and Australia, there is a significant amount of existing case law on this subject.[75] Expert evidence based on complex computer models is also accepted in a range of civil proceedings across various jurisdictions, particularly those cases involving environmental and health matters. Courts are therefore likely to be comfortable and willing to accept event attribution science in climate change litigation, subject to its being robustly interrogated, as is the case with any other expert evidence. The approval of the methodologies used in event attribution science by the National Academy of Sciences may be relevant in establishing that the techniques used in event attribution studies form part of a body of expertise that is generally accepted in the scientific community.

3.2. *Standards of proof and factual versus legal causation*

As noted by various authors, science and law take very different approaches to cause and effect, and the standard of proof.[76] This is perhaps unsurprising, given that the law's concern is with limiting the categories of legal liability in order to promote certainty in the face of changing facts, while science is characterised by an openness to change and adaptability to alternative hypotheses.

Despite this, both disciplines are concerned with establishing 'truth' or 'proof' of cause and effect. In general, the law's traditional 'but for' test[77] for causation applies

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74 Claire McIvor, 'Debunking Some Judicial Myths about Epidemiology and Its Relevance to UK Tort Law' (2013) 21 Medical Law Review 553.

75 See the UK Civil Evidence Act 1972, s 3 and the Civil Procedure Rules, Pt 35. In *Barings plc (in liquidation) v Coopers & Lybrand (No 2)* [2001] Lloyd's Rep. P.N. 379, [2001] EWHC Ch 17, the court held that expert evidence is admissible if the court accepts that there is an acknowledged 'body of expertise', governed by recognised standards and rules of conduct, capable of influencing the court's decision on any of the issues that it has to decide. In the US, the *Daubert* standard applies. In that case, the US Supreme Court found that in order to determine the reliability of a scientific opinion, the court may look at any relevant factor, but courts pay particular attention to four factors named in *Daubert*: whether the expert's theory has been or can be tested; whether it has been subjected to peer review and publication; the known or potential error rate of the technique; and whether the technique is generally accepted in the scientific community. Daubert v Merrell Dow Pharmaceuticals, Inc. 509 U.S. 579 (1993) at 593–94. Helpful summaries for the interpretation of this rule in each US state are available at this link: www.theexpertinstitute.com/daubert-v-frye-a-state-by-state-comparison/?utm_source=email&utm_medium=email&utm_content=blog-daubert-v-frye&utm_campaign=4.4.17.

76 See a detailed discussion in Robert Young, Michael Faure and Paul Fenn, 'Causality and Causation in Tort Law' (2004) 24 International Review of Law and Economics 507.

77 The simplest expression of *necessary* causation, defined as when the event can *only* occur in the presence of the causal factor, although other factors may also be necessary.

a basic counterfactual analysis, similar to that applied by event attribution. Both approaches consider the world in the absence of a particular factor (in law, the allegedly negligent conduct), in order to demonstrate cause and effect.[78]

However, the standard varies at which each discipline will be satisfied that causation is established. Scientists seek to demonstrate results that are proven with greater than 90 per cent certainty (ie, where the uncertainty in results is reduced to less than ten per cent),[79] while the law in civil matters is willing to accept as proven evidence that is shown to be correct 'on the balance of probabilities' or 'more likely than not'[80] (that is, with certainty of greater than 50 per cent). As an English judge has stated:

> it has often been said that the legal concept of causation is not based on logic or philosophy. It is based on the practical way in which the ordinary man's mind works in the everyday affairs of life.[81]

Recognising this, there is a long tradition of courts' acceptance of expert evidence based on probabilistic statistical methodologies such as those used in event attribution.[82] Analogous to event attribution, the health impacts of various risk factors such as pesticides, smoking or asbestos inhalation can only be quantified in probabilistic terms.

The law in both England and Wales and the US has addressed the issue of who should be held accountable where the plaintiff cannot identify specific individuals or entities responsible for the damage or loss complained of, but can identify a group of individuals or entities responsible for the acts or operations which ultimately caused the damage or loss.[83] The common law has therefore evolved to establish liability and allocation schema even where scientific evidence has been incapable of determining strict causal links between loss and damage and the acts of a particular defendant (such as in the case of asbestos, pharmaceuticals, water pollution or contaminated land). In certain types of negligence cases, in England and Wales, courts have accepted probabilistic evidence as proving causation between the wrongful conduct

78 K. Mengersen, S.A Moynihan and R.L Tweedie, 'Causality and Association: The Statistical and Legal Approaches' (2007) 22 Statistical Science 227; A. Hannart and others, 'Causal Counterfactual Theory for the Attribution of Weather and Climate-Related Events' (2016) 97 Bulletin of the American Meteorological Society 99.

79 See National Academy of Sciences, *Advancing the Science of Climate Change* (2010) 491 available at www.nap.edu/read/12782/chapter/26 accessed 22 March 2018.

80 Or, on the balance of probabilities.

81 Lord Reid in McGhee v National Coal Board [1973] 1 W.L.R. 1, [1956] 1 All ER 615 HL(Sc), at 4F.

82 Discussed in the UK case of *Heneghan v Manchester Dry Docks Ltd* [2016] 1 W.L.R. 2036, [2014] EWHC 4190 (QB).

83 In England and Wales, the 'material contribution test' modifies the 'but for' test. To succeed the plaintiff must show (on the balance of probabilities) the defendant's tortious actions materially contributed to the injury. The 'material contribution' test allows an injured party to avoid the need to prove 'but for' causation and only requires proof that the negligent action materially contributed to the claimant's injury. *McGhee v National Coal Board* [1973] 1 WLR 1 (HL); *Sido John v Central Manchester and Manchester Children's University Hospitals NHS Foundation Trust* [2016] 4 W.L R. 54, [2016] EWHC 407 (QB). The 'material contribution to the risk' test has also been developed in England and Wales although it is currently limited to mesothelioma (exposure to asbestos dust) cases. To succeed, the plaintiff must prove that defendant's negligence materially contributed to the risk of injury (ie, more than de minimis) to recover damages in full. A distinction is made between indivisible and divisible injuries *Sienkiewicz v Grief (UK) Ltd* [2011] 2 A.C. 229, [2011] UKSC 10.

and the claimant's disease when such evidence demonstrates that the risk of the event occurring was increased by a factor of 2:1, known as the 'doubling of the risk' test. To succeed the claimant must show (on the balance of probabilities) by means of expert epidemiological evidence that his or her tortious exposure to a disease-causing agent doubled the risk that he or she would otherwise have had of contracting the disease[84] (although we note that it has been argued that English courts have often misinterpreted statistical evidence).[85] In *Heneghan v Manchester Dry Docks Ltd*, the Court of Appeal described the doubling of the risk test as follows:

> [i]f statistical evidence shows that tortfeasor more than doubled the risk that the victim would suffer the injury, it follows that it is more likely than not that the tortfeasor caused the injury.[86]

The doubling of risk test does not apply in England and Wales in mesothelioma (asbestos dust) cases, where a more relaxed standard of 'material contribution to the risk' was developed in the *Fairchild* line of cases,[87] in order to provide redress to victims of mesothelioma who could not identify which employer caused their disease. Given the controversy surrounding these cases, and the judicial remorse expressed for the relaxation of this test,[88] 'material contribution to risk' seems presently unlikely to be applied outside the mesothelioma context in the UK. The reasoning in these judgments is nevertheless useful in considering the ways in which judges have relaxed traditional deterministic tests for causation.

In the US, liability for negligence is limited by the concept of proximate cause, which is called 'scope of liability' and the 'risk standard' under the Restatement

84 *XYZ v Schering Health Care Ltd* [2002] EWHC 1420 (QB), (2003) 70 BMLR 88; *Novartis Grimsby Ltd v John Cookson* [2007] EWCA Civ 1261; B v Ministry of Defence [2010] EWCA Civ 1317; (2011) 117 B.M.L.R. 101.

85 See n 74 above.

86 [2016] EWCA Civ 86, [2016] 1 WLR 2036 [8]. See also comment of Justice Jay in *Heneghan v Manchester Dry Docks Ltd & Ors* [2014] EWHC 4190 (QB) [26] in which the court said:

> [f]irst, in the event that the epidemiological evidence clearly establishes that the relative risk is greater than 2:1, the concepts of 'increasing the risk' and 'causing the damage' are, in effect, synonymous. This is exactly the situation which obtains in the present case in the context of the asbestos versus the smoking risk. The relative risk was greater than 2:1 (and by a significant margin, once the multiplicative effects are brought to bear), the risk was therefore increased, and the damage was therefore caused, as a matter of probability. At that point, of course, the common law adopts the fiction – in relation to a past event – of that having been found more probable than not being certain. In purely scientific terms one may not 'know' that to be so, but anyone using that verb in such a context is implicitly applying a higher standard of proof.

87 In England and Wales, this test was applied in the context of mesothelioma cases in which medical evidence was only able to show that a person's risk of harm was increased by the defendant's conduct: see *Sienkiewicz v Greif* [2011] UKSC 10, [2011] 2 AC 229 and *Fairchild v Glenhaven Funeral Services Ltd* [2002] UKHL 22, [2003] 1 AC 32. In each of these cases there were multiple negligent employers and the plaintiff could not identify any that had doubled his risk of disease. In these cases, the court relaxed the test to one of 'material contribution to the increase in risk' on public policy grounds, although these cases have been highly controversial with *Fairchild* reversed by UK parliamentary legislation (Compensation Act 2006).

88 See Lord Hoffmann, '*Fairchild* and After' in Andrew Burrows, David Johnston and Reinhard Zimmermann (eds), *Judge and Jurist: Essays in Memory of Lord Rodger of Earlsferry* (Oxford University Press 2013) 63–70.

(Third) of Torts (Am. Law Inst. 2010).[89] Foreseeability is both consistent with and informs the concept of proximate cause (eg, the 'scope of liability' or 'risk standard').[90] While the Restatement 3rd frames this discussion in the negative, with a focus on lack of sufficient foreseeability operating to limit liability, the focus of this paper is the increasing probability of certain events attributable to anthropogenic GHG emissions and how that probability makes specific risks and impacts from climate change foreseeable with statistical certainty – making the risks foreseeable and fit squarely within the 'scope of liability' or – said otherwise – the proximate cause. As such, when science informs a fact finder, through expert testimony, that certain events and/or consequences are more likely than not, highly likely or characterised using defined numerical ranking, the evaluation of probabilistic causation (or legal causation) description, the legal analysis known as 'proximate cause' (or the scope of liability) proceeds. In other words, the determination of the 'scope of liability' defined by section 29 of the Restatement (Third) of Torts: Liability for Physical Harm[91] requires that the harm complained of must be the direct result of the risks presented by the tortious conduct and is informed to the extent that the attribution science defines the foreseeability of the event in a manner that the actor knew or reasonably should have known under the circumstances. However, it should be noted that the proximate cause analysis evaluates the foreseeability of the event or other relevant cause in the context of placing limits on the 'scope of liability'.[92] In the case of attribution science, the proximate cause evaluation will likely focus on the foreseeability of the impacts of climate change for the defendant party. In some circumstances, the law may seek to determine whether the impacts of climate change could or should have been reasonably anticipated or forecast by the defendant given all relevant circumstances.[93]

89 Restatements of the Law are a set of treatises on legal subjects published by the American Law Institute and drafted by judges, academics and practitioners, that seek to inform judges and lawyers about general principles of common law. Despite their influence, they do not define the law nor are they always followed in adjudication.

90 'When properly understood and framed, the foreseeability standard is congruent with the risk standard adopted by this Section for negligence cases.' Restat 3d of Torts: Liability for Physical and Emotional Harm, s 29 (3rd 2010); and 'Many jurisdictions employ a "foreseeability" test for proximate cause, and in negligence actions such a rule is essentially consistent with the standard set forth in this Section. Properly understood, both the risk standard and a foreseeability test exclude liability for harms that were sufficiently unforeseeable at the time of the actor's tortious conduct that they were not among the risks – potential harms – that made the actor negligent. Negligence limits the requirement of reasonable care to those risks that are foreseeable. See § 3, Comment g.' Restat 3d of Torts: Liability for Physical and Emotional Harm, s 29 (3rd 2010).

91 Restatement (Third) of Torts (Am. Law Inst. 2010): Liability for Physical Harm.

92 'Many jurisdictions employ a "foreseeability" test for proximate cause, and in negligence actions such a rule is essentially consistent with the standard set forth in this section. Properly understood, both the risk standard and a foreseeability test exclude liability for harms that were sufficiently unforeseeable at the time of the actor's tortious conduct that they were not among the risks – potential harms – that made the actor negligent. Negligence limits the requirement of reasonable care to those risks that are foreseeable. Restatement (Third) of Torts s 3 cmt. g (Am. Law Inst. 2010): Liability for Physical and Emotional Harm s 29.

93 'To apply this rule requires consideration, at an appropriate level of generality, see Comment i, of: (a) the risks that made the actor's conduct tortious, and (b) whether the harm for which recovery is sought was a result of any of those risks. Risk is explained in § 3, Comment e, as consisting of harm occurring with some probability. The magnitude of the risk is the severity of the harm discounted by the probability that it will occur. For purposes of negligence, which requires foreseeability, risk is evaluated by reference to the foreseeable (if indefinite) probability of harm of a foreseeable severity. If a strict-liability claim does not require foreseeability, the concept of risk can be determined by examining

When considering the importance of attribution science in informing the foreseeability analysis upon which key portions of the proximate cause analysis turns, the Restatement 3rd recognises that the proximate cause analysis is adjusted when evaluation of an affirmative duty, such as that of a professional or other contracting third party is involved, requiring that the duty of reasonable care be considered.[94] The Restatement also recognises that other adjustments to the proximate cause analysis – determining the scope of liability – are necessary when a public entity is involved.[95] And where negligence per se exists, for example, violation of a statute, the proximate cause analysis is still recognised as being informed by foreseeability[96] – and thus, in this case, attribution science. However, even these special adjustments will consider foreseeability of harm in the analysis and, as such, attribution science is absolutely relevant to and will inform the liability analysis.

This has been discussed to illustrate that the English and US courts have been willing to find exceptions to the traditional deterministic 'but for' test for causation in certain circumstances. The discussion also demonstrates that event attribution science is theoretically capable of proving a sufficient 'causal' connection between human greenhouse gas emissions and an extreme weather event in the law (if the doubling of the risk test or alternative proximate causation test were to be adopted).

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the severity and probability in retrospect. See Comment j.' Restat 3d of Torts: Liability for Physical and Emotional Harm, s 29 (3rd 2010).

94 Restat 3d of the Law, Torts: Liability for Physical and Emotional Harm, s 37 (3rd 2010); and 'An actor who undertakes to render services to another and who knows or should know that the services will reduce the risk of physical harm to the other has a duty of reasonable care to the other in conducting the undertaking if:

(a) the failure to exercise such care increases the risk of harm beyond that which existed without the undertaking, or
(b) the person to whom the services are rendered or another relies on the actor's exercising reasonable care in the undertaking.'

Restat 3d of the Law, Torts: Liability for Physical and Emotional Harm, s 42 (3rd 2010).

95 '*i. Affirmative duties of public entities.* The imposition of affirmative duties on public entities poses two distinct problems. First, there is the concern that the judicial branch give appropriate deference to a coordinate branch of government when a decision allocates resources or involves other significant political, social, or economic determinations. See § 7, Comment *g*. The "public duty" doctrine, which denies a tort-law duty to provide police, fire, and other protective services to members of the public generally, reflects this concern. Second, unlike private persons and entities, governmental entities exist, in significant part, to protect the public from risks that are created by others. Law enforcement, fire protection, building inspection, and social services are only a few of the many governmental operations that provide a significant protective function. The limitless potential liability that might be visited on government entities if affirmative duties were imposed on them for every undertaking has influenced courts in limiting the existence and scope of affirmative duties to which government entities are subject. Some courts insist on a "special relationship" between the plaintiff and a public entity that distinguishes the plaintiff from the public at large before imposing an affirmative duty. The "special relationship" invoked by these courts should be distinguished from the special relationships described in §§ 40 and 41.'
Restatement (Third) of Torts: Liability for Physical and Emotional Harm, s 37 (A. Law Inst. 2010); however, it should be noted that, in many US jurisdictions, public entities waive sovereign immunity in gross up to specified limits of liability and in specific for certain activities.

96 Restatement (Third) of Torts: Liability for Physical and Emotional Harm, s 38 (A. Law Inst. 2010).

For example, a 2016 rapid event attribution study found that anthropogenic climate change made temperature anomalies in the Coral Sea (which led to widespread bleaching of coral in the Great Barrier Reef) 175 times more likely to occur.[97] This study may therefore satisfy the 'doubling of the risk' test with such damage having been clearly 'caused' by anthropogenic emissions. We therefore agree with Hannart and others' conclusion that event attribution scientists could more confidently express their findings as proving a causal relationship between human influence and weather,[98] when communicating with certain non-scientific stakeholders.

3.3. *Liability for greenhouse gas emissions*

At prezsent, there is no legal precedent or statute making greenhouse gas emissions a strict liability exposure, and most industrial-scale emissions are emitted legally under environmental authorisations from states. However, as is often the case in the US, for example, mere compliance with the law does not eliminate liability exposure entirely, especially in common law torts, and such laws are drafted with the expectation that the common law will provide a gap-filling function. Often, science and public knowledge and community sentiment move faster than the regulatory system and related statutory laws. In such situations, where the evidence shows that a risk exists, the law may require that defendants act consistently with their obligations under the common law, even if a statute requires less – unless the statute expressly declares that the statute pre-empts common law claims (exclusive jurisdiction). Thus, despite the fact that greenhouse gas emissions are not prohibited, in several jurisdictions there are arguments that rights (constitutional or human) to a safe climate or a safe and healthy environment require impact analysis and may impose consequent legal obligations on sovereign bodies, as well as private parties, to act to protect citizens' rights or to prevent foreseeable injury or harm. Although legislative action would likely be required to make greenhouse gas emissions a strict liability exposure, we discuss below some concepts that have previously been relevant to the development of norms or rules governing liability for other substances that cause bodily injury.

3.3.1. Fungibility

A key issue associated with establishing specific causation in relation to a particular private or state party is the scientific evidence that greenhouse gas emissions are inherently fungible. That is, greenhouse gas emissions are mutually interchangeable in their environmental impact and their effect on the atmosphere, as it is the overall concentration of greenhouse gases in the atmosphere that ultimately determines the extent of atmospheric warming (taking account of the latent warming impact of those gases).[99]

97 ARC Centre of Excellence for Climate System Science, 'Barrier reef attribution study: data and methodology' (28 April 2016) www.climatescience.org.au/content/976-barrier-reef-attribution-study-data-and-methodology accessed 22 March 2018.

98 See n 78. Of course, scientists should continue to express their findings probabilistically; however, they should be aware that the law does not adopt such rigorous standards when drawing conclusions about cause and effect (nor, arguably, does the general public).

99 IPCC AR5 Synthesis Report (n 3), Figure 2.3 at 63 and Table 2.2 at 64.

This concept of fungibility forms the basis of emissions trading schemes around the world, including the European Union's Emissions Trading Scheme.[100] This has implications for the legal concept of specific causation, because it means that all emissions from various sources around the world (adjusted to a carbon dioxide equivalent value)[101] contribute equally to the phenomenon of global warming over time. It also means that, for the purposes of considering the contributions of various parties to climate change, on a global basis, the total quantities of carbon dioxide equivalent emissions emitted by different actors may be used as the basis for attributing responsibility among states or private parties. This approach is well accepted by the scientific community, industry, states and civil society, and is used as the basis for calculating projected future emissions.[102] The fact that voluntary greenhouse gas emissions accounting schemes, regulations and treaties address accounting for regulation of greenhouse gas emissions using CO_2eq (carbon dioxide equivalency) based standards suggests that industry, NGOs and regulators all see and, in fact, treat greenhouse gas emissions as fungible in practice.

The fungibility of greenhouse gas emissions has important implications for the development of liability of states and private actors for the loss and damage associated with climate change. In the future, it could provide the basis for statutes similar to the US federal scheme for managing the costs and liabilities of contaminated land, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This statute establishes specific remediation obligations or compensation, and joint and several liability for specific actors joined by a facility or other nexus.[103] The European Environmental Liability Directive is another example of a strict liability regime for certain environmental incidents.[104] Similarly, legislation seeking to recover the public health costs of tobacco-related disease from producers and marketers of tobacco products has been enacted in British Columbia and in Florida.[105]

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100 Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC [2003] OJ L 275/32.

101 Some greenhouse gases, including methane, have greater heat-trapping potential than carbon dioxide in the atmosphere, but are often adjusted to an equivalent value of carbon dioxide (the most common greenhouse gas), or a unit in metric tonnes of CO_2 equivalent, known as the GWP or global warming potential of the gas. This is usually done in accordance with the methodology contained in the summarised in the Greenhouse Gas Protocol and provided for in various UNFCCC decisions. Greenhouse Gas Protocol 'Global Warming potential Values' http://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf accessed 22 March 2018.

102 The Greenhouse Gas Protocol is the most widely used greenhouse gas accounting tool for private organisations and sub-national governments: www.ghgprotocol.org/about-us. Nation states use the IPCC's methodology as provided for by the UNFCCC: https://unfccc.int/national_reports/annex_i_ghg_inventories/reporting_requirements/items/5333.php.

103 United States Environment Protection Agency, Superfund: CERCLA Overview (July 2017) www.epa.gov/superfund/superfund-cercla-overview accessed 22 March 2018.

104 Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage [2004] OJL143/56.

105 Tobacco Damages and Health Care Costs Recovery Act 2000 (BC); Medicaid Third-party Liability Act 409.910 Fla Stat (1995). The passage of the Florida legislation led to the 1998 Master Settlement Agreement between tobacco companies and nearly 50 US states. See Martin Olszynski and others (n 64).

In rare cases, the law has developed special legal doctrines to accommodate situations where the adversarial process cannot achieve fact finding or truth due to unique inequities in knowledge between the parties. For example, the 'market share' theory was developed to address this situation in highly technical and scientifically dependent pharmaceutical litigation, in cases where an injured plaintiff could not identify which negligent drug manufacturer had caused their disease.[106] The concept of fungibility is fundamental to the underpinnings of the market share theory of allocating liability.

Whether climate change liability and damages could be adjudicated using the market share theory is an open question that will depend on the degree to which greenhouse gas emissions are accepted as fungible by the law, and the extent to which those responsible for those emissions can be clearly identified.[107]

There are several reasons courts are unlikely, at this point in time, to extend market share theory to cases regarding greenhouse gas emissions. US courts have been hesitant to extend this doctrine beyond medical negligence cases.[108] Attempting to bring market share cases regarding climate change would likely raise public policy concerns, including questions regarding the cumulative impact of emissions from all actors, the appropriate scope of liability, and social norms regarding climate justice and the social usefulness of the emitting activities.[109] Nevertheless, some scholars have discussed in detail the establishment of a statutory scheme for recovery of damages from the fossil fuel industry, drawing parallels with the tobacco industry's Master Settlement Agreement.[110] However, it is beyond the scope of this article to examine potential future liability of major greenhouse gas emitters – this article instead focuses on the present implications of event attribution science for the legal duties of governments

106 See *Sindell v Abbott Laboratories*, 26 Cal 3d 588 (1980) (creating and applying market share liability in the first instance). The California Supreme Court was influenced by a law review article, Naomi Sheiner 'DES and a Proposed Theory of Enterprise Liability' (1978) 46 Fordham L Rev 963. Market share liability theory is similar to alternative liability in that they both allow plaintiffs to shift the causation burden of proof to defendants in certain circumstances. See generally Mark A Geistfeld, 'The Doctrinal Unity of Alternative Liability and Market-Share Liability' (2006) 155 University of Pennsylvania Law Review 447, citing Dan B. Dobbs, Paul T. Hayden and Elllen M. Bublick, 'The Law of Torts § 175', at 428 Dan B. Dobbs, The Law of Torts, (West Group 2000), s 175.

107 See Christina M Carroll and others, *Climate Change and Insurance* (American Bar Association 2012) ('if the plaintiff can demonstrate that GHG emissions are fungible, the injury was caused by GHG emissions, and that it has joined in the action a "substantial percentage" of the companies responsible for those emissions, the causation burden could shift, forcing the defendant seeking to avoid liability to prove that it was not responsible for the emissions leading to the alleged harm.').

108 For example, they did so in the case of DES, or diethylstilbestrol, a synthetic hormone manufactured by about 300 drug companies. It was prescribed to an estimated five million pregnant women between 1947 and 1971 in an effort to reduce miscarriages: Associated Press, 'Jury Awards $42.3 Million to Women in Drug Lawsuit' (9 January 1994) www.nytimes.com/1994/01/09/nyregion/jury-awards-42.3-million-to-women-in-drug-lawsuit.html?mcubz=0 accessed 22 March 2018; see also William D Wilson, 'Market Share Liability – Did New York Go Too Far?: Hymowitz v. Eli Lilly & Co.' (2012) 64(2) St John's Law Review, Article 7.

109 Krishna Rao Pinninti, *Climate Change Loss and Damage: Economic and Legal Foundation* (Springer 2014) at 31 (noting extreme scope of climate change loss and damages); John S Gray and Richard O Faulk, 'Negligence in the Air? Should Alternative Liability Theories Apply in Lead Paint Litigation?' (2008) 25 Pace Envtl L Rev 147, 149 fn 1 (noting that causation-in-fact serves both to assign blameworthiness and to 'limit[] the scope of potential liability and thereby encourage[] useful activity that would otherwise be deterred if there were excessive exposure to liability').

110 See Olszynski and others (n 64).

and private parties to adapt to a changing climate where extreme heat, drought and storms are more frequent and/or severe.

3.3.2. Potential unique climate impact monitoring obligations

In special circumstances regarding product and other pollutant exposures where loss or damage takes a long time to appear (characteristics of latency), US law has developed a special doctrine to find a defendant liable for a defective product (or in similar circumstances), despite the lack of current actual physical damage to plaintiffs. Where impacts are latent in nature and the scientific evidence demonstrates that it is more likely than not that, given exposure levels, latent damages are expected to later emerge, defendants are held liable for the costs of ongoing medical monitoring to exposed plaintiffs for a period consistent with the expected latency period.[111] Should those monitoring results demonstrate latent damage, additional liability may attach to the defendants for loss during the latency monitoring period and beyond the mere monitoring costs. The inquiry created by the doctrine is a five-step complex scientific and factual inquiry designed to level the playing field for those parties exposed to a latent defect in a product.[112] While this approach to liability allocation focuses solely on the medical monitoring of the development of human disease, parallels exist in the climate change damage space. Some climate change impacts include increased risk of disease, while others are damage to the environment and increased safety risks (and other risks) to humans. Linking product liability to climate change, as discussed above, is complex and fraught with legal causation barriers. Nevertheless, where the product availability is uniquely controlled by a sovereign body, interesting possibilities arise with respect to using such a theory to require a sovereign body to populate its own administrative record with medical monitoring data for the purposes of creating a documentation trail of recognised impacts and – thus – foreseeability of harm. Whether a court would be willing to extend this theory to include an obligation for continued monitoring beyond medical monitoring – such as environmental monitoring that looks for specific conditions with direct impacts on human safety, for example, extreme weather events – is an unexplored but interesting question. Attempts to extend medical monitoring theory to applications for credit monitoring related to a cyber-security breach have been rejected by a court but only because an intervening criminal act would be required to create the ultimate damage[113] – a situation absent in the context of climate change-induced damages.

4. Implications for legal duties of care

The implications of event attribution science are not limited to legal claims against states or private entities. Advancements in the *foreseeability* of increased risk of

111 Victor E Schwartz and Cary Silverman, 'The Rise of "Empty Suit" Litigation®. Where Should Tort Draw the Line?' (2015) 80 Brook L Rev 599; https://m.mayerbrown.com/Files/Publication/cdc5dd0c-84e0-4b3f-8faf-bd791fe716a9/Presentation/PublicationAttachment/cc7c0655-35cc-41ec-ba46-6453e21a3426/medical_monitoring.pdf; www.iadclaw.org/assets/document/Toxic_Hazardous_Substances_April_2015.pdf.

112 *Potter v Firestone Tire & Rubber Co*, 6 Cal 4th 965, 1007-08 (Cal 1993).

113 *Reilly v Ceridian Corporation*, 11-1738 (3rd Cir 12-12-2011); see also www.casemine.com/search/us?q=toxic±exposure±medical±monitoring±cases.

extreme weather and associated losses also have implications for a range of public and private actors who have duties to protect or of trust and loyalty, including public authorities, engineers and company directors.

As discussed above, foreseeability of harm is relevant to the assessment of each element of the tort of negligence: duty of care, breach and 'proximate cause' (eg, 'scope of liability').

4.1. *Duties of government*

The Office of the High Commissioner for Human Rights, the United Nations Environment Programme (UNEP) and the IBA have all acknowledged that climate change affects the exercise and enjoyment of a range of human rights, and that, accordingly, states have duties both to mitigate emissions and to ensure resilience.[114]

To date, these types of climate-related claims have had the greatest success in domestic courts. Together with other claims brought against states under administrative or statutory provisions, event attribution science is likely to provide strong evidence of particularised harm to individuals. Although early American cases based on tort law principles had limited success,[115] new cases based on state and federal public trust doctrines have been successful in Washington[116] and in preliminary stages at the federal level.[117]

In Europe, where the state fails to prevent foreseeable violations of citizens' fundamental rights (or fails to warn them about risks to such rights), in certain circumstances the state may be found to have violated an individual's human rights.[118] The European Court of Human Rights has found that states have violated their human rights obligations under the European Convention on Human Rights (ECHR) by allowing environmental harm to occur through failures to follow environmental standards, or to provide citizens with appropriate information regarding environmental risks.[119] It is likely that event attribution studies, similar to the study produced after the European heatwave of 2003, will be critical in proving that lethal extreme weather events were caused or made more likely by foreseeable climatic changes.

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114 Office of the High Commission for Human Rights (OHCHR), Discussion Paper: Understanding Human Rights and Climate Change, Submission of the OHCHR to the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (2015); United Nations Environment Programme, 'Climate Change and Human Rights' (2015); International Bar Association Task Force n 55., John H Knox, 'Human Rights Principles and Climate Change' in Cinnamon P Carlarne, Kevin R Gray and Richard G Tarasofsky (eds), *The Oxford Handbook of International Climate Change Law* (Oxford University Press 2016).

115 *Kivalina v ExxonMobil*, 663 F Supp 2d 863 (ND Cal 20 September 2009); *Native Village of Kivalina v ExxonMobil Corp*, 696 F 3d 849, 854 (9th Cir 2012); *American Electric Power Co, Inc et al v Connecticut*, 564 US (2011); Cecilia O'Connell Miller, 'Climate Change Litigation in the Wake of *AEP v Connecticut* and *AES v Steadfast*: Out to Pasture, But Not Out of Steam' (2012) 5 Golden Gate U Envtl LJ 343; *Comer v Murphy Oil*, 585 F 3d 855 (5th Cir 2009).

116 *Foster v Washington Department of Ecology*, No 14-2-25295-1 (Sup Ct Wash 19 November 2015).

117 *Juliana v United States of America et al*, Case No 6:15-ev-01517-TC, US District Court for the District of Oregon.

118 Christopher Hilson, 'Risk and the European Convention on Human Rights: Towards a New Approach' in Catherine Barnard and Okeoghene Odudu (eds), *The Cambridge Yearbook of European Legal Studies 2008–2009* (Hart Publishing 2009) 353–75.

119 *Lopez Ostra v Spain* (1994) 20 EHRR 277; *Budayeva and Others v Russia* App no 15339/02 (ECtHR, 20 March 2008); *Öneryildiz v Turkey* (2005) 41 EHRR 20.

The state of climate science and attribution science also has important implications for government officials at all levels who may have cause to consider this science when carrying out their duties. In the US, claims against governments for failing to adapt to climate change may be brought under existing statutory obligations,[120] negligence,[121] fraud or takings theories.[122] All these causes of action have the potential to be affected by the state of attribution science. In England and Wales, the test for establishing a duty of care in negligence is threefold and requires consideration of (1) whether the resultant harm was foreseeable; (2) whether there is sufficient proximity between the parties; and (3) whether it is fair, just and reasonable to impose a duty in the circumstances.[123] Whether the courts impose a duty of care on a particular actor will depend on the weighing of these three factors; however, foreseeability is a relevant element. It is difficult to predict the extent to which public policy concerns around imposing additional duties on public authorities will interact with the elements of foreseeability, but it is clear the latest attribution evidence may have a role to play in resolving these issues.

In the US, lawsuits have already been filed seeking to hold governments responsible for damages resulting from failure to adapt crucial infrastructure to shifting flood risk.[124] These lawsuits are somewhat unique in that they are affected by the extent to which the waiver of sovereign immunity applies,[125] and the kinds of constitutional claims that may be brought. In fact, one such case was successful on constitutional grounds.[126]

This category of claim could potentially be driven by insurers, who may be faced with contractual duties to provide coverage when the source of the loss is difficult if not impossible to mitigate because they are under the control of a sovereign body or a utility. In *Illinois Farmers Insurance Co v Metro Water Reclamation District of*

120 As discussed in Jessica Wentz, 'Planning for the Effects of Climate Change on Natural Resources' (2017) 47(3) Environmental Law Reporter 10220.

121 Maxine Burkett, 'Duty and Breach in an Era of Uncertainty: Local Government Liability for Failure to Adapt to Climate Change' (2013) 20 George Mason Law Review 775.

122 Jennifer Klein, 'Potential Liability of Governments for Failure to Prepare for Climate Change' (Sabin Center for Climate Change Law, Columbia Law School, August 2015) http://web.law.columbia.edu/sites/default/files/microsites/climate-change/klein_-_liability_of_governments_for_failure_to_prepare_for_climate_change.pdf accessed 22 March 2018.

123 *Caparo Industries plc v Dickman* [1990] UKHL 2, [1990] 2 AC 605.

124 See *Re Katrina Canal Breaches Litig*, 696 F 3d 436, 441 (5th Cir 2012) (holding that the US Army Corps of Engineers had immunity from tort liability regarding its construction and operation of a navigational channel that subsequently increased storm surge and flooding during Hurricane Katrina). The issue of municipal liability is an emerging one. See Decision, *Tzakis v Berger Excavating Contractors, Inc*, No 09-CH-06159 (Circuit Court of Cook County, Ill 3 April 2015) (dismissing claims against area water reclamation district, township and city under the Public Duty Rule, which 'provides that a public entity is not liable for its failure to provide adequate governmental services because the duty to provide such services is owed to the general public at large, and not to any particular plaintiff or plaintiffs') (internal quotations omitted); *Illinois Farmers Insurance Company v Metropolitan Water Reclamation District of Greater Chicago*, No 14-CH-06608 (Ill Cir Ct Cook Co) (lawsuit, subsequently withdrawn, brought by insurance company against local government for failing to adapt to climate change).

125 Dobbs (n 106) at 693–95 (discussing typical immunities of governments to tort claims); *ibid* at 695–715 (discussing waivers of immunity by the US federal government); *ibid* at 715–32 (discussing waivers by state governments).

126 *St Bernard Parish Gov't v United States*, 121 Fed Cl 747 (2015) (holding that the US Army Corps of Engineers violated the US Constitution by failing to construct and operate adequately a navigational channel that subsequently increased storm surge and flooding during Hurricane Katrina).

Greater Chicago[127] and related cases, the insurers of many homeowners experiencing repeated sewer back-up claims and concomitant extreme basement damages argued that Chicago-area had acted arbitrarily – signing climate action plans on the one hand, but refusing to acknowledge climate change in the management of its waste water utilities – in breach of its duties to safely store storm water and remedy property damage from serious recurring flooding events. The plaintiffs claimed that the public authority failed to adequately plan for increased storm events arising from climate change rainfall increases. Although the claims were withdrawn,[128] they provide an interesting example of the kind of issues that event attribution science raises for both infrastructure planners and those responsible for maintenance, but also a variety of insurance contracts.

As with negligence claims more generally, lawsuits against governments raise complicated value judgements and reveal conflicting instructions given to government officials.[129] For example, government procurement rules that specify particular design standards may no longer be protective in the face of climate change – such as procurement rules that reference 1970s vintage rainfall tables as the determinative rainfall amount reference for design criteria.[130] Because procurement regulations are slow to change, such statutes will present similarly challenging disputes or claims from damage, depending upon the circumstances. The state of attribution science will certainly be relevant to those discussions and related disputes.

In Australia, which has had the largest volume of litigation relating to climate change-related environmental risks, disputes have most frequently arisen in the context of town planning law and regulation.[131] As noted by Peel and Osofsky, adaptation planning in Australia has mainly been dealt with by local and state governments, in the context of wildfire, flooding and land use planning management frameworks. Additional regulation tends to be adopted after significant natural disasters, such as the 2009 Black Saturday bushfires in Victoria,[132] with subsequent attempts to

127 See, eg, *Illinois Farmers Insurance Co v Metro Water Reclamation District of Greater Chicago*, No 1:14-cv-03251 (ND Ill complaint filed in state court on 17 April 2014) (class action alleging that city water reclamation district and towns failed to increase their stormwater storage capacity, allowing a heavy rainfall to flood more than 600 homes in 2013 such that a "reasonably foreseeable" rainfall fell in Cook County in April 2013 and caused water to overflow from the storm and sanitary sewer systems and invade the properties of hundreds of homeowners insured by Farmers); Notice of Dismissal, *ibid* (entered on 4 June 2014).

128 Summer Hunter Book, 'Farmers Insurance withdraws Class ACtion Alleging Fauilure to Adapt to Clmate Change (Columbia Law School, 16 June 2014) http://blogs.law.columbia.edu/climatechange/2014/06/16/farmers-insurance-withdraws-class-action-alleging-failure-to-adapt-to-climate-change accessed 22 March 2018.

129 James Wilkins, 'Is Sea-Level Rise Foreseeable? Does It Matter?' (2011) 26 Journal of Land Use & Environmental Law 437. This author of this article notes that judicial deference to the complex judgements required to be made by governments could be eroded by enhanced predictive capabilities, and suggests that 'the imprudence of poor planning decisions and land use controls will become more evident and unacceptable with each passing year and decade' at 488–89.

130 For example, the US Army Corps of Engineers design manual uses ten-year and 100-year storm or rainfall amounts based on historical data calculations as discussed on this USGS page https://water.usgs.gov/edu/100yearflood.html. These standards are retrospective and do not include forecasts for changes in climate predicted over the expected life of the asset to be constructed. This approach assumes stationarity – which is of course lost with climate change.

131 See Jacqueline Peel and Hari M. Osofsky (n 2).

132 On 9 February 2009, after 173 people died in Australia's worst ever bushfire disaster, the Victorian government established a Royal Commission into the disaster, which recommended additional requirements being imposed into the planning framework, including a 'Bushfire Management Overlay'

'reduce green tape' having reversed many of these regulatory changes. Liability risk for infrastructure providers, however, remains, and may be increasing as a result of event attribution science that predicts more frequent extremely hot summers and subsequent increased wildfire risk.[133]

In 2011, the Australian Local Government Association commissioned a private law firm to complete a comprehensive review of the liability risks to local government that may arise as a result of climate change. The report concluded that, in order to mitigate liability risks:

> [c]ouncils must ensure they keep up to date with general climate change science and information related to mitigation and adaptation strategies and also information particular to their specific local government area. … Councils will require localised information on impacts on which they can rely when making planning decisions and specialist advice on planning and engineering options for other aspects of adaptation.[134]

We agree with Burkett, who notes that:

> if mistake, lack of competence or wilful ignorance on the part of local entities result in more devastating damage from climate change, it is manifestly unfair and dangerously costly to have those harmed bear the burden alone.[135]

4.2. *Duties of professionals*

4.2.1. Professional negligence claims

In common law jurisdictions (including the US, UK, Canada and Australia) the typical case for negligence requires proving that the defendant owed the plaintiff a duty, the duty was breached and the breach was the cause of damages suffered by the plaintiff. Foreseeability affects each of these elements,[136] especially (in the US) the proximate cause analysis because awareness of a risk changes fairness concerns that are part of the proximate cause analysis.[137]

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applicable to areas of highest fire risk. The disaster also led to the largest class action litigation settlement in Australian history against several electricity providers and line maintenance contractors who had not adequately maintained electricity infrastructure, sparking several fires: see *Matthews v AusNet Electricity Services Pty Ltd & Ors* [2014] VSC 663.

133 Justine Bell-James, Mark Baker-Jones and Emilie Barton, *Legal Risk: A Guide to Legal Decision Making in the Face of Climate Change for Coastal Decision Makers* (CoastAdapt Information Manual 6, National Climate Change Adaptation Research Facility 2016).

134 Baker & McKenzie, *Local Council Risk of Liability in the Face of Climate Change: A Report for the Australian Local Government Association* (July 2011) www.environment.gov.au/system/files/resources/d9b2f9cf-d7ab-4fa0-ab0e-483036079dc7/files/alga-report.pdf accessed 22 March 2018.

135 Maxine Burkett (n 121) 778.

136 Dobbs (n 106) 277 ('Since no one tries to avoid risks that cannot be identified or harms that cannot be foreseen as a possibility, the reasonable person exercises care only about the kinds of harm that are foreseeable to reasonable people and risks that are sufficiently great to require precaution') (citations omitted); *ibid* at 336 ('[W]hen courts say that harm is unforeseeable, they may mean that although harm was actually foreseeable on the facts of the case, a reasonable person would not have taken action to prevent it because the risk of harm was low, and harm was so improbable that a reasonable person would not have taken safety precautions. Put differently, there was a recognized risk of harm, but the risk was not unreasonable.'); *ibid* at 444 (relevance of foreseeability to proximate cause analysis); *ibid* at 448–49 (differentiating between foreseeability analysis in determining negligence and in determining proximate cause).

137 Dobbs (n 106) 453–54, 463–64, 466 (discussing relevance of foreseeability in proximate cause analysis).

Attribution science is likely to be highly relevant to future cases against professionals for failing to consider climate change impacts when designing and implementing projects, and managing and upgrading physical infrastructure.[138] Licensed professionals, including engineers, architects, planners and environmental consultants, often have unique and special duties to actual and expected users of their services and work. These duties can arise under contract, at common law or under statutes governing the licensure of professionals, expanding their exposure and responsibilities. Because improvements in attribution science will likely affect the foreseeability of physical climate change effects, attribution science will likely change the reasonableness of following existing design methods, which have, at their core, assumptions about the continued relevance of stationarity.[139]

The state of climate science and attribution science, and in particular how these affect regional weather patterns and catastrophic events, will be critical to planners as well as design and construction professionals. Many professional associations and organisations recognise this, and are implementing policy to address these emergent risks.[140] Engineering and other professionals may need to maintain awareness of the rapidity of advances in event attribution science, and adapt their advice and actions accordingly. We note that, in the UK, the Climate Change Act 2008 provides the Secretary of State with the power to request that public authorities produce a report on the steps they are taking to prepare for climate change.[141] Organisations that have reported

138 Richard Lord and others, *Climate Change Liability: Transnational Law and Practice* (Cambridge University Press 2012) 36–37 (noting the likely 'increasing practical importance' of liability based on failing to account for climate change, particularly against architecture, engineering or similar entities); *ibid* at 37 ('Buildings which crack, flood or blow over, dams, flood defenses and firebreaks which fail, roads or railways which buckle in extremes of heat or droughts – these are all likely to be sources of climate change liability.').

139 A *stationary* time series is one whose statistical properties such as mean, variance, autocorrelation, etc are all constant over time (see stationarity and differencing of time series data – Duke People https://people.duke.edu/~rnau/411diff.htm) and stationarity as applied to atmospheric water cycle: a fundamental principle of hydrology is that the hydrologic water cycle is statistically stationary – in other words, what we experience as rain, snow, humidity, etc geospatially is statistically stationary – and we experience that as local climate – that it is characterised by stationarity. 'Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.' See P.C.D Milly and others, 'Stationarity Is Dead: Whither Water Management?' (2008) 319 Science 573, 573.

140 Such as the Principles of Climate Change Adaptation for Engineers developed by the Canadian Engineering Qualifications Board, which are a set of principles for engineers to assist them in considering the implications of climate change in their professional practice, available at https://engineerscanada.ca/sites/default/files/01_national_guideline_climate_change_adaptation.pdf accessed 22 March 2018 or the report by the Royal Academy of Engineering, *Infrastructure*, *Engineering and Climate Change Adaptation: Ensuring Services in an Uncertain Future* (2011) www.raeng.org.uk/publications/reports/engineering-the-future accessed 22 March 2018; efforts are under way at the American Society of Civil Engineers to evaluate the need to change infrastructure design standards to reflect climate change, see http://theicnet.org/wp-content/uploads/2015/07/2015-07-ASCE-Practice-to-Climate-Change-2015.pdf; efforts are also under way at the American Society of Chemical Engineers – see www.aiche.org/chenected/2017/07/paic-climate-task-force-general-approaches.

141 Climate Change Act 2008, s 62 provides:

'(1) The Secretary of State may direct a reporting authority to prepare a report containing any of the following –

(a) an assessment of the current and predicted impact of climate change in relation to the authority's functions;

(b) a statement of the authority's proposals and policies for adapting to climate change in the exercise of its functions and the time-scales for introducing those proposals and policies;

in accordance with such a request include major regional water and electricity utilities, the Bank of England and public land managers.[142]

In the US, the threat of litigation for professional negligence was used in an administrative rate-making proceeding to challenge a utility's effort to recoup construction costs by increasing rates,[143] challenging the reasonableness of the reconstruction costs that, the utility sought to pass through to ratepayers. This approach resulted in a settlement process in which the parties negotiated a more resilient reconstruction of utility assets after Superstorm Sandy.[144] This demonstrates that claims relating to failure to consider climate change adaptation may arise in a number of unpredictable ways.

As negligence law evolves in the climate change sphere, it will also likely have to balance the multiple different values at stake. For instance, in the matter involving the Consolidated Edison Company of New York (ConEd), as in many cases involving consumer protection regulation, there is a tension between the desire to keep costs low for ratepayers and the need to (re)construct with sufficient resilience to handle expected extreme weather events in the face of climate change. If negligence suits advance past procedural hurdles, courts may need to wrestle with these complicated value judgements.

As attribution science improves in fidelity, foreseeability will increase in lockstep. As such, we can expect to see an expanding scope of liability, which is equated to proximate cause under the Third Restatement of Torts, with respect to considering and anticipating climate change as an integral component of professional duty.

4.2.2. Implications for corporations and their directors

It is increasingly recognised by companies and corporate leaders that the business risks of climate change go beyond the reputational, and encompass:

> loss of competitiveness due to reputational damage and/or higher energy costs, legal risks from emissions regulation and private litigation, an inability to transfer risk (via mechanisms such as insurance), and market risks as investors and credit providers limit their own exposures to emissions-intensive sectors.[145]

In the UK and now globally through the establishment of a Task Force on Climate-related Financial Disclosures (TCFD) by the G20's Financial Stability Board[146]

(c) an assessment of the progress made by the authority towards implementing the proposals and policies set out in its previous reports.'

142 Committee on Climate Change, 'Adaptation Reporting Power: Second Round Review' (March 2017) www.theccc.org.uk/wp-content/uploads/2017/03/Adaptation-Reporting-Power-Second-round-review-Committee-on-Climate-Change-March-2017.pdf accessed 22 March 2018.

143 Matter 13-00197, Case No 13-E-0030, Consolidated Edison Company of New York, Inc, New York State Department of Public Service (filed 25 January 2013).

144 Joint Proposal, Case No 13-E-0030 et al (filed 31 December 2013); Order Approving Electric, Gas and Steam Rate Plans in Accord with Joint Proposal, Case No 13-E-0030 et al (issued 21 February 2014).

145 Sarah Barker, 'Directors' Duties in the Anthropocene: Liability for Corporate Harm Due to Inaction on Climate Change' (December 2013) 9 http://responsible-investmentbanking.com/wp-content/uploads/2014/11/Directors-Duties-in-the-Anthropocene-December-2013.pdf accessed 22 March 2018.

146 An international forum for governments and central bank governors of 20 major economies. Its objective is to promote international financial stability.

(chaired by Michael Bloomberg), this debate has been brought to the attention of mainstream financial markets. A seminal 2015 report[147] and speech by Mark Carney, governor of the Bank of England, categorised the financially material risks of climate change into three classes, being:

- physical (including those arising from changes in weather patterns, with impacts on assets, resources and infrastructure and the associated business interruptions to services and supply chains);
- transition (arising from shifts to operating context as a result of regulation to restrict emissions or the disruption caused by alternative technologies); and
- liability risks (litigation arising from third parties or as a result of failures to manage physical or transition risks).

Financial regulators in France, Australia and Canada[148] have also announced investigations into the impacts of climate-related risks to macro-prudential financial stability. Major international institutional investors including BlackRock,[149] Mercer[150] and ratings agencies including Moody's[151] and S&P[152] have recognised the financial implications of climate change and are increasingly developing systems to measure climate risks, and are forcefully engaging with companies to explain their risk mitigation practices. New tools, such as Evonet,[153] are emerging to track climate-related disclosures in a systematic manner. At present, much of this activity has focused on voluntary disclosure regimes such as the TCFD and the CDP (formerly the Carbon Disclosure Project),[154] although there are clear legal requirements for risk disclosure in many jurisdictions that have the potential to expose companies to litigation risk.[155]

The same legal principles discussed above in the context of professionals dealing with the built environment apply to the directors of private and public corporations. In many jurisdictions, such individuals owe fiduciary (or similar) duties directly to

147 See n 54.
148 See n 54.
149 BlackRock, 'Our engagement priorities for 2017-2018' (2018) www.blackrock.com/corporate/en-us/about-us/investment-stewardship/engagement-priorities#climate-risk assessed 22 March 2018.
150 See n 53.
151 Moody's, 'Moody's sets out approach to assessing the credit impact of physical climate change on sovereigns' (7 November 2016) www.moodys.com/research/Moodys-sets-out-approach-to-assessing-the-credit-impact-of–PR_357629 accessed 22 March 2018.
152 Standard & Poors Rating Services, *Insights: Climate Risk: Rising Tides, Raise the Stakes* (December 2015) www.spratings.com/documents/20184/984172/Insights±Magazine±-±December±2015/cff352af-4f50-4f15-a765-f56dcd4ee5c8 accessed 22 March 2018.
153 See www.envonet.com/landing/ and www.globenewswire.com/news-release/2017/07/10/1041930/0/en/Envonet-Simplifies-Searches-for-Corporate-Environmental-Financial-Disclosures.html.
154 www.cdp.net/en.
155 In 2016, ClientEarth complained to the UK's Financial Reporting Council (FRC) about two UK listed oil and gas companies, Cairn Energy and SOCO International, regarding their disclosure of climate-related risks to their business. The complaints alleged that both companies had failed to adequately disclose climate risk in their annual reports, contrary to the legal requirements of the Companies Act 2006 (UK). In 2017, both companies included additional climate disclosures in their annual financial filings and strategic reports. Copies of the complaints are available at www.documents.clientearth.org/library/download-info/cairn-regulatory-complaint and www.documents.clientearth.org/library/download-info/soco-regulatory-complaint.

their companies requiring them to act in the best interests of the company, to act with reasonable prudence, due diligence, care and skill, and to avoid conflicts of interest. Some academic research[156] and legal opinion[157] now indicates that failures to manage and mitigate climate risks may constitute a breach of a director's duties to the corporation, and may result in personal liability if corporate value becomes impaired in the future. In particular, a recent Australian legal opinion has noted that the climate change label tends to obscure the risk management issue, stating that:

> [i]f the country is to experience more frequent and intense storms, for example, of the type that might cause flooding and power outages, then directors of companies exposed to such risks should be considering them regardless of whether or not they are perceived to be brought about by climate change, and regardless of the regulatory outlook. In this sense, 'climate change' has the potential to be a distracting label. The question is really whether there is a foreseeable risk to the interests of a company.[158]

It is clear that event attribution science will be crucial to the development of these standards of reasonable conduct, as more frequent and intense floods, wildfires, heatwaves and storms disrupt a range of assets and infrastructure systems.

Failure to adequately disclose climate-related risks, or the withholding of certain information from the market, has the potential to trigger securities fraud legislation, such as New York's Martin Act.[159] The New York Attorney General has been investigating whether ExxonMobil violated its obligations under state law to disclose material information regarding climate change to investors.[160] New York's investigation has

156 See n 145 above. Also see Commonwealth Climate and Law Initiative, 'Concerns Misplaced: Will Compliance with the TCFD Recommendations Really Expose Companies and Directors to Liability Risk?' (September 2017) www.smithschool.ox.ac.uk/research/sustainable-finance/publications/CCLI-TCFD-Concerns-Misplaced-Report-Final-Briefing.pdf accessed 22 March 2018.

157 An eminent Australian barrister and Queen's Counsel, Noel Hutley QC, together with NSW barrister Sebastian Hartford-Davis, provided an opinion on the extent to which the law requires Australian company directors to respond to climate change risks, concluding this to be the case where such risks are material to the interests of the company. The opinion also concluded that company directors are potentially exposed should they fail to take such matters into account in their operational decision-making processes. The opinion is available at https://cpd.org.au/wp-content/uploads/2016/10/Legal-Opinion-on-Climate-Change-and-Directors-Duties.pdf accessed 22 March 2018.

158 See n 157 at 9. This sentiment was echoed by the CEO of Australian utility AGL who told the *Guardian* newspaper that 'It's nothing to do with the science – it's irrelevant what I believe. If markets believe it, if customers believe it, if investors believe it, if government is making policy, then what I have is a significant risk in my portfolio that I have to mitigate'; see Michael Slezak and Martin Farrer 'AGL boss: regardless of climate science, it's time to drop the 'emissions business' (Guardian, 23 February 2016) www.theguardian.com/australia-news/2016/feb/24/agl-boss-regardless-of-climate-science-its-time-to-drop-the-emissions-business accessed 22 March 2018.

159 For example, the US coal giant Peabody Coal signed a notice of discontinuance with the New York Attorney General in November 2015. This followed an investigation into the company for misrepresentations in official filings regarding its ability to reasonably predict the impact of greenhouse gas regulation on its future business, and for an incomplete discussion of the International Energy Agency's projections relating to the future coal demand (by omitting less favourable scenarios). See Assurance of Discontinuance, No 15-242, in the Matter of Investigation by Eric T Schneiderman, Attorney General of the State of New York, of Peabody Energy Corporation, http://ag.ny.gov/pdfs/Peabody-Energy-Assurance-signed.pdf.

160 There were news reports in January 2016 that California Attorney General Kamala D Harris is investigating ExxonMobil's knowledge of climate change based on previously published reports analysing internal company documents, although her office has declined to confirm the investigation. Ivan Penn, 'California to Investigate whether Exxon Mobil Lied about Climate-Change Risks' *Los Angeles Times* (20 January 2016) www.latimes.com/business/la-fi-exxon-global-warming-20160120-story.html; John

also escalated: in November 2015, the New York Attorney General issued a subpoena to ExxonMobil allegedly demanding documents dating back to 1977 related to climate change, including research related to its causes and effects.[161] More recent filings allege that the company may have misled investors for several years regarding its approach to climate risk, with the Attorney General telling the New York Supreme Court that it had found no evidence that the company applied a 'proxy cost of carbon' as reported in annual financial filings.[162]

In these disclosure cases, climate attribution can inform the elements required to demonstrate materiality. If the climate change attribution science is certain and the litigation discovery yields proof of special knowledge attributing climate change to emissions of the same or fungible type related to products or operations of the company on the part of the defendant – where such attribution could have material financial impacts on the regulated stock issuing entity – then that creates liability under the Martin Act (which does not require scienter).[163] If scienter can also be proven, then liability may attach under other theorem and statutory provisions related to shareholder disclosure obligations and liability of directors, officers and the companies they represent.[164]

In 2010, the Securities and Exchange Commission (SEC) recognised the financial impacts of climate change when it issued Interpretive Guidance on climate disclosure, outlining expectations from companies in reporting on 'material' regulatory, physical and indirect risks and opportunities related to climate change.[165]

If prior investigative actions against Dynegy, Xcel, AES and Peabody[166] are predictive of the outcome from the ExxonMobil subpoena, some additional disclosures related to potential climate-related regulatory impacts on the companies may be made, but actual discussion of the science and knowledge about climate change will be avoided. Overall, the New York state securities developments suggest that the path to defining responsibility for climate change, at least in the US, is likely to involve consideration of what some oil-producing companies knew about climate change at particular points in time.[167] This may lead to claims under securities statutory liability regimes as well as product liability schema.

Schwartz, 'California Said to Target Exxon in Climate Inquiry' *New York Times* (20 January 2016) www.nytimes.com/2016/01/21/science/california-said-to-target-exxon-in-climate-inquiry.html?_r=1.

161 See, eg, Justin Gillis and Clifford Krauss, 'Exxon Mobil Investigated for Possible Climate Change Lies by New York Attorney General' *New York Times* (5 November 2015) A1.

162 Sophie Marjanac, 'Executive Perspective: Latest New York filing asks if Exxon is still lying to investors about how it manages carbon risk' (Thomson Reuters, 14 June 2017) http://sustainability.thomsonreuters.com/2017/06/14/executive-perspective-latest-new-york-filing-asks-if-exxon-is-still-lying-to-investors-about-how-it-manages-carbon-risk accessed 22 March 2018.

163 Known as 'mental intent' in the UK/Australia.

164 United States Federal Securities Act of 1934 Rule 10-b.

165 Securities and Exchange Commission, 17 CFR PARTS 211, 231 and 241, [Release Nos. 33-9106; 34-61469; FR-82] Commission Guidance Regarding Disclosure Related to Climate Change (2010).

166 See various settlements agreements with the New York Attorney General, relating to disclosure. New York State office of the Attorney General, 'Attorney General Cuomo Announces Agreement With AES to Disclose Climate Change Risks to Investors' (November 19, 2009) https://ag.ny.gov/press-release/attorney-general-cuomo-announces-agreement-aes-disclose-climate-change-risks-investors accessed 22 March 2018. https://ag.ny.gov/press-release/attorney-general-cuomo-announces-agreement-aes-disclose-climate-change-risks-investors. And the link to the settlement document https://ag.ny.gov/sites/default/files/press-releases/archived/AES%20AOD%20Final%20fully%20executed.pdf accessed 22 March 2018.

167 http://exxonknew.org.

The recent recommendations from the TCFD may ultimately translate into a mandatory obligation to disclose climate risks as a condition of participating in the international banking and securities systems. While currently this is a voluntary standard, related regulatory actions in other countries may have an impact on the global marketplace. As such, the US SEC may be forced to move beyond the policy declared to a development of a specific audit and evaluation scheme to ensure the continued ability of companies with securities to participate in global financial markets. This is a developing situation of interest and, as disclosures move from the realm of the qualitative to the quantitative, annual reports and related disclosures will certainly be informed by attribution science.

Obviously, to the extent that the TCFD creates a common law standard of care for accountants, liability independent of statutory requirements may attach to professional accountants or auditors,[168] creating an alternative path to disclosure. It is also possible that efforts may be made to enhance the disclosure requirements for climate change related risks in the short term, at least outside the US. Many large institutional investors have been active in insisting that insurers disclose climate-related risks.[169] These trends are only likely to escalate as attribution science improves and human influence on extreme weather is increasingly recognised by scientists and the general public.

5. Conclusion

As attribution science develops, the foreseeability of an event increases, which affects the analysis for multiple areas of law, particularly the legal duties of those with the power to influence outcomes, or legal duties to manage and mitigate risks and harms, such as by changing a design or providing a warning. Improvements in attribution science may therefore increase the likelihood that courts will be willing to issue both traditional and novel and far-reaching injunctive relief restraining action; or, in the future, rulings that require defendants to pay damages to plaintiff parties adversely affected by the impacts of climate change.

For this reason, this article has suggested that the next set of litigation issues will likely turn on whether improvements in attribution science can show what scientists knew or know about climate change, and thus what effects or events can be totally or partially attributed to climate change and what was reasonably foreseeable. The first cases will likely be brought in circumstances where there is a specific adaptation

168 For details see ClientEarth, 'Risky Business: Climate Change and Professional Liability Risks for DB Investment Advisers' and 'Risky Business: Climate Change and Professional Liability Risks for DB Pensions Actuaries' (2017) www.clientearth.org/new-reports-bring-light-climate-liability-risks-facing-pensions-advisers.

169 Jim Coburn and Jackie Cook, 'Cool Response: The SEC and Corporate Climate Change Reporting' (CERES February 2014) 28–36. There have been efforts within the insurance industry to address these and similar environmental issues. See UNEP Finance Initiative (UNEP FI) Survey, 'Advancing the Role of the Insurance Industry in Climate Change Adaptation'; UNEP FI Principles for Sustainable Insurance (PSI) (the insurance company members of UNEP FI developed the PSI, which are intended to promote the integration of environmental, social and governance (ESG) issues across an insurance company's spheres of influence); National Association of Insurance Commissioners (NAIC) Climate Disclosure Survey www.namic.org/regbod/naic/climate-risk accessed 22 March 2018.

action (other than reducing emissions) that the defendant could have taken to reduce harm to the plaintiff.

As attribution science continues to improve, this knowledge will inform the applicability and availability of legal theorem for liability adjudication – ranging from the well-trodden path of assessing professional liability, to the emerging discussion of constitutional rights to a safe climate – and sovereign obligations under the public trust doctrine, as well as the availability of unique doctrine and related damages like market share theory, (medical) monitoring damages for latent defects and quantitative and qualitative disclosure obligations for securities offerors, owners, traders and investors.