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THE LAW AND SCIENCE OF CLIMATE CHANGE ATTRIBUTION

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I. Introduction

There is overwhelming scientific agreement that human activities are changing the global climate system and that these changes are already affecting human and natural systems. Significant advances in climate change detection and attribution science—the branch of science that seeks to isolate the effect of human influence on the climate and related earth systems—have continued to clarify the extent to which anthropogenic climate change causes both slow onset changes and extreme events.[1] The spike in deaths and costs associated with extreme events and the prospect for slow onset changes with irreversible impacts has inspired a marked increase in the number of lawsuits seeking to hold different actors—particularly governments and fossil fuel companies—accountable for their contribution to or failure to take action on climate change.[2]

Attribution science is central to recent climate litigation, as it informs discussions of responsibility for climate change. Climate science also plays a central role in policymaking and planning, particularly where decisions need to be made about how to allocate the costs of mitigating and adapting to climate change. This Article describes the role that attribution science has played in recent litigation as well as policymaking and planning activities, and discusses future directions in the law and science of climate change attribution, addressing questions such as how attribution science can better support policymaking and help resolve questions of liability and responsibility for climate change.

Editors' Note: This Article is excerpted from Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution,* 45 Colum. J. Env't L. (2019), *and is reprinted with permission.*

1. U.S. Global Change Research Program, Climate Science Special Report, Fourth National Climate Assessment (2017).
2. *See* Michael Burger & Justin Gundlach, U.N. Env't Programme, The Status of Climate Change Litigation 10-26 (2017); Michael Burger & Jessica Wentz, *Holding Fossil Fuel Companies Accountable for Their Contribution to Climate Change: Where Does the Law Stand?*, 74 Bull. of the Atomic Scientists 397 (2018).

II. Scientific Underpinnings

A. Core Concepts and Terminology

Generally speaking, detection and attribution is a two-step process used to identify a causal relationship between one or more drivers and a responding system. The first step—detection of change—involves demonstrating that a particular variable has changed in a statistically significant way without assigning cause.[3] The second step—attribution—involves sifting through a range of possible causative factors to determine the role of one or more drivers with respect to the detected change.

1. Scope of Detection and Attribution Research

Detection and attribution with regards to climate change can be broken down into several interrelated parts or research streams:

- **Linking climate change to anthropogenic drivers:** How are human activities affecting the global climate system?
- **Linking impacts to climate change:** How do changes in the global climate system affect other interconnected natural and human systems?
- **Identifying the relative contribution of various emission sources and land use changes:** To what extent have different sectors, activities, and entities contributed to anthropogenic climate change?

3. *See, e.g.*, David R. Easterling et al., *Detection and Attribution of Climate Extremes in the Observed Record*, 11 Weather Climate Extremes 17 (2016).

We refer to these three areas of research as *climate change attribution*, *impact attribution*, and *source attribution*. In addition to those areas of research, we discuss extreme event attribution as a separate category of attribution research.

2. Data Sources and Analytical Techniques

a. Climate Change, Extreme Event, and Impact Attribution

There are several key sources of information and analytical techniques that are used in climate change, impact, and extreme event attribution studies: physical understanding, observational data, statistical analysis, and models.[4] Physical understanding refers to scientific understanding of physical properties and processes, such as the heat-trapping effects of greenhouse gases (GHGs). Observational data is data that can be observed and measured, such as in situ measurements of carbon dioxide concentrations and satellite measurements of sea surface temperature. For attribution, statistical analysis refers to mathematical formulas, models, and techniques that are used to quantify the probability of an observed change occurring with and without anthropogenic forcing on the climate. Models use quantitative methods, including predictive equations and statistical techniques, to simulate interactions within the climate system. Climate models use quantitative methods, including predictive equations and statistical techniques, to simulate interactions within the climate system and generally involve at least two sets of simulations, differing only in that one is meant to reflect the world that is, and the other is meant to reflect a "counterfactual" world without anthropogenic climate change (or without some component of anthropogenic climate change).

b. Special Considerations for Extreme Event and Impact Attribution

Extreme event and impact attribution deal with more geographically and temporally distinct forms of change (e.g., how much has sea level risen in a particular city in the past 20 years). Natural variability, unrelated to changes in climate forcing, is larger at fine spatial and temporal scales, making it harder to identify signals associated with anthropogenic or other forcings. Further, impact attribution studies must also account for non-climate variables—that is, characteristics of human and natural systems that are not part of the climate system—and confounding variables—which influence both dependent and independent variables in a study and can lead to spurious associations between a driver and an event or impact. The number of non-climate and confounding variables increases as attribution research moves toward an analysis of discrete impacts on humans, communities, and ecosystems.

c. Source Attribution

While there is some overlap in terms of the data collection and analytical techniques used for source attribution, source attribution studies also rely on different types of evidence, particularly documentary evidence of GHG emissions and carbon sequestration impacts. Documentary evidence refers to information contained in documents and reports, such as national GHG emissions inventories or corporate GHG disclosures, detailing GHG emissions or carbon sequestration impacts from a particular activity or source.

III. Legal and Policy Applications

This part addresses the salience of attribution science to policymaking at various scales of governance, its role in planning and environmental impact assessment, and the critical role it has played and will play in climate change litigation.

A. Policymaking

Attribution science helps build support for actions to address the causes and impacts of climate change by (i) demonstrating that anthropogenic climate change is already underway and resulting in adverse impacts and (ii) lending confidence to model projections of how the climate will change in response to GHG emissions and how these changes will affect people and the environment in the decades to come.[5]

Attribution science can also contribute to more effective mitigation and adaptation policies. For mitigation policy, attribution science can be used to determine which actors, activities, or sectors should be targeted for regulation or to determine the appropriate level of regulation for any given source category. Meanwhile, information about impact attribution can help policymakers identify the most significant climate change-related risks and make prudent decisions about how to allocate resources for adaptation.[6] Attribution science can also help decisionmakers better understand the cost of unabated climate change, thus informing and justifying decisions about the appropriate level of regulation (e.g., the right price of a carbon tax).

Finally, attribution science provides a framing mechanism for international negotiations by helping build political support for ambitious action on climate change, providing a basis for critiquing countries that do not go far enough with their emission reduction pledges,[7] improving

4. *See, e.g.*, Sophie Marjanac & Lindene Patton, *Extreme Weather Event Attribution Science and Climate Change Litigation: An Essential Step in the Causal Chain?*, 36 J. Energy & Nat. Res. L. 265, 271-72 (2018).

5. *See* Easterling et al., *supra* note 3.

6. *See id.*; Sebastian Sippel et al., *Stakeholder Perspectives on the Attribution of Extreme Weather Events: An Explorative Enquiry*, 7 Weather, Climate, Soc'y 224, 229 (2015).

7. Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104, art. 14, ¶ 1 (establish-

decisionmaking about how to allocate funds for adaptation, and helping countries reach agreement on the highly contentious "loss and damage" framework.[8]

B. Planning and Environmental Impact Assessment

Attribution science facilitates on-the-ground planning for the effects of climate change by providing more robust data about how climate change is already affecting landscapes, ecosystems, and human systems such as cities, infrastructure, and food production. This information can feed into scenario planning, informing the likely and possible ranges of outcomes under different GHG emission trajectories.[9] Attribution studies that focus on regional or localized impacts can be used to develop and refine downscaled projections of climate change impacts within a particular geographic region and to improve the accuracy and precision of the models that are used to develop those projections.[10]

C. Litigation

Below, we present a breakdown of how attribution science is used in the context of several legal issues: (1) establishing standing to sue; (2) introducing expert scientific testimony and reports as evidence; (3) challenges to government failures to regulate GHG emissions; and (4) lawsuits seeking to hold emitters liable for damages from climate change impacts.

1. Establishing Standing to Sue Sources of GHG Emissions for Climate-Related Harms

Standing doctrines address the question of who should have access to courts to adjudicate a particular claim. The U.S. Supreme Court has held that plaintiffs must establish that (i) they have suffered an injury-in-fact—that is, "an invasion of a legally protected interest which is (a) concrete and particularized and (b) actual or imminent, not conjectural or hypothetical"[11]; (ii) the injury-in-fact is fairly traceable to the defendants' allegedly unlawful actions[12]; and (iii) the injury could be redressed by a favorable court decision.[13] Attribution science is central to standing contests over each of these prongs.

While the requirement of particularized injury has been viewed as a potential barrier for plaintiffs seeking standing based on injuries caused by climate change, since such injuries are often shared by the public, some plaintiffs have successfully used impact attribution research to persuade the courts that their injuries are sufficiently particularized for standing purposes.[14] With respect to causation, in cases brought against governments and private actors for failure to regulate or abate emissions, the Supreme Court has found sufficient causation where the emissions represent a "meaningful contribution" to global climate change.[15] Finally, the redressability prong requires that it is likely and not "merely speculative" that the injury would be redressed by a favorable decision.[16]

2. Evidentiary Standards for Scientific Testimony and Reports

A threshold consideration regarding the role of attribution science in the courtroom is whether expert testimony on attribution is admissible in court. The *Daubert* standard, first articulated by the Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals*,[17] is the contemporary standard for admissibility in federal courts and many states courts. That standard charges the judge with ensuring that the basis of the expert's testimony is "scientific knowledge,"[18] and outlines the following factors for making this determination:

- Whether the scientific theory or technique can be (and has been) tested
- Whether it has been subjected to peer review and publication
- Whether it has a known error rate
- Whether it has a degree of "general acceptability" within a "relevant scientific community."[19]

Most attribution studies accord with the *Daubert* standard insofar as they rely on scientific theories that can be tested using models, statistical analyses, and observations; they are typically published in peer-reviewed journals; they typically discuss known sources of bias and the potential for Type I and Type II errors; and they are based on generally accepted techniques. However, defendants in climate lawsuits may argue that some of the more novel impact and event attribution techniques do not meet all four requirements—and in particular, the requirement of "general acceptance" within the scientific community—or challenge testifying scientists who draw inferences from

ing a "global stockade" whereby the parties to the agreement "shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals").

8. For more on this topic, see Christian Huggel et al., *Reconciling Justice and Attribution Research to Advance Climate Policy*, 6 Nature Climate Change 901 (2016).
9. *See* Easterling et al., *supra* note 3.
10. *See, e.g.*, Mohammad Reza Najafi et al., *Attribution of the Observed Spring Snowpack Decline in British Columbia to Anthropogenic Climate Change*, 30 J. Climate 4113 (2017).
11. Lujan v. Defs. of Wildlife, 504 U.S. 555, 560, 22 ELR 20913 (1992).
12. *Id.*
13. *Id.* at 561.
14. *See, e.g.*, Massachusetts v. EPA, 549 U.S. 497, 525, 35 ELR 20148 (2007); Connecticut v. Am. Elec. Power Co., 582 F.3d 309, 39 ELR 20215 (2d Cir. 2009), *rev'd*, 564 U.S. 410 (2011).
15. *See Massachusetts*, 549 U.S. at 525.
16. *Lujan*, 504 U.S. at 561.
17. 509 U.S. 579, 23 ELR 20979 (1993).
18. *Id.* at 592.
19. *Id.* at 592-95.

attribution studies with respect to impacts not explicitly covered in those studies.[20]

3. Lawsuits Challenging the Failure to Regulate GHG Emissions

Environmental and citizen groups in the United States and other jurisdictions have brought numerous challenges seeking to compel governments to take action to curtail GHG emissions. There are three types of lawsuits that fall within this category: (i) lawsuits challenging the government failure to implement statutory mandates with respect to air pollution control; (ii) lawsuits challenging the failure to protect public health pursuant to general legal mandates recognized in constitutions, public trust doctrines, human rights law, and other legal sources; and (iii) lawsuits involving administrative decisions undertaken within an existing regulatory scheme, typically decisions to grant or refuse an authorization for a particular activity. In all three types of cases, attribution science comes into play when plaintiffs need to establish a causal connection between the government's action or inaction and concrete harms caused by climate change to succeed on the merits.

4. Lawsuits to Hold Emitters Liable for Damages Caused by Climate Change Impacts

In addition to suing governments for failure to regulate GHG emissions, some plaintiffs have gone directly to the source, suing major emitters and fossil fuel companies, in an attempt to obtain an injunction against future emissions or monetary damages for adaptation costs. To date, these lawsuits have been predominately domestic, and based on tort or tort-like theories such as public nuisance, private nuisance, and negligence.[21] Attribution science is central to these climate tort cases, as it is necessary to establish a causal connection between the defendant's emissions or activities and plaintiffs' injuries, and that the injuries were a foreseeable result of the emissions. Below, we summarize the key elements of tort cases and briefly touch on how attribution science may help with establishing these elements.

a. Elements of Negligence and Nuisance

i. Duty

Where foreseeability of harm to the specific plaintiff is an element of tort duty,[22] the history and current and future states of attribution science will play a role in establishing and defending against it. However, even in a case where foreseeability is not required to establish legal duty,[23] plaintiffs cannot evade the issue of foreseeability. It will come up in establishing proximate cause.

ii. Breach

Once a duty has been established, liability can only attach if there has been a breach, in some form, of that duty. In the negligence context, a breach occurs where the plaintiff has failed to exercise reasonable care to protect others from a foreseeable risk of harm.[24] In nuisance, the breach factors into an assessment of whether defendant's interference with plaintiff's person, property, or public goods was "unreasonable."[25] In both instances, the "reasonableness" inquiry involves something of a "social welfare cost-benefit test."[26] In climate tort cases, attribution science is the connective tissue tying particular impacts resulting in particular costs back to climate change and anthropogenic influence on climate change, and it can help improve calculations of the social cost and benefits of GHG emissions.[27] Courts will also consider foreseeability when assessing the reasonableness of conduct. Again, attribution science plays an obvious role in this inquiry, helping to establish that a reasonable person would anticipate that activities that generate GHG emissions or otherwise contribute to climate change will eventually result in specific types of harmful impacts.

iii. Causation

The plaintiff must show that the defendant's conduct was both the factual—which is further divided into general, or generic, causation and specific, or individualized, causation—and the proximate, or legal, cause of the injury.[28] In regards to general causation, one critical question is whether and under what circumstances courts will impose liability on an actor who is not the sole cause of the injury. In failure-to-regulate cases, some courts have granted standing based on a showing that the unregulated emissions made a "meaningful contribution" to climate change.[29] Or consider toxic tort cases—which are not dissimilar from tort actions undertaken against GHG emitters—where liability may be apportioned among potentially responsible parties through statistical, probabilistic, and epidemiological studies.[30] Where the probability that a particular defendant's substance caused a substantial portion of the harm reaches

20. For more on this topic, see Kirsten Engel & Jonathan Overpeck, *Adaptation and the Courtroom: Judging Climate Science*, 3 Mich. J. Env't & Admin. L. 1 (2013).
21. Burger & Wentz, *supra* note 2.
22. *See, e.g.*, Norris v. Corr. Corp. of Am., 521 F. Supp. 2d 586, 589 (W.D. Ky. 2007).
23. *See, e.g.*, Rodriguez v. Del Sol Shopping Ctr. Assocs., L.P., 326 P.3d 465, 467 (N.M. 2014); Thompson v. Kaczinski, 774 N.W.2d 829, 835 (Iowa 2009).
24. Restatement (Second) of Torts §283 (Am. L. Inst. 1965).
25. *Id.* §826.
26. Douglas A. Kysar, *What Can Climate Change Do About Tort Law*, 41 Env't L. 1, 21 (2011).
27. *Id.* at 22-23 (discussing application of the federal Social Cost of Carbon to American Electric Power).
28. Michael Byers et al., *The Internationalization of Climate Damages Litigation*, 7 Wash. J. Env't L. & Pol'y 264, 279 (2017).
29. *See, e.g.*, *Massachusetts*, 549 U.S. at 525 (emissions from all U.S. motor vehicles made a "meaningful contribution" to global climate change).
30. Byers et al., *supra* note 28.

a certain threshold, then courts may be willing to impose liability for the harm.

In regards to specific causation, the critical question is "whether defendant's actions or behavior were 'a necessary element' in bringing about the injury."[31] Assuming one can show that climate change is responsible for a particular local climate-related phenomenon or event that produced an injury, and before one gets to issues of contributory negligence, the problem for proving climate harms here is clear: emissions of any one actor, or even any small set of actors, will be difficult to pin down as a "but-for" cause of impacts arising from anthropogenic climate change.[32]

In contrast to the factual causation inquiry, which focuses on scientific relationships, proximate cause is intended to address whether the injury is sufficiently closely related to the allegedly wrongful conduct, such that it makes sense to impose liability on the defendant. To answer this question, courts may consider factors such as the geographic and temporal proximity between the conduct and the injury (and more generally, the directness of the relationship between conduct and injury), and whether the injury was a foreseeable result of the conduct.[33]

iv. Harm or Injury

Regardless of the tort, actual harm must be shown. Here, again, attribution science would be used in the ways described above—both as a means of characterizing the injury (interference) to the plaintiff, and as a means of explaining why the interference is unreasonable and a threat.

b. Role of Attribution Science

Attribution science can be used to establish three key elements in tort litigation: foreseeability, causation, and injury. A court's determination as to whether an impact is a foreseeable consequence of activities that increase GHG emissions would likely depend on: (i) the degree of confidence with which the impact has been attributed to climate change or projected to occur as a result of climate change; (ii) the amount of scientific research linking the impact to climate change (and level of consensus among scientists); and (iii) the time frame in which that research was performed. If there are only a handful of studies on a particular impact or if the studies were all published after the allegedly tortious conduct, then courts might conclude that the impacts are not foreseeable. Further, the actual injuries associated with climate change are often secondary or tertiary impacts that are influenced by a multitude of confounding factors in addition to anthropogenic influence on climate. The greater the number of confounding factors, the more difficult it may be to establish that a particular injury was foreseeable.

In most tort cases invoking climate change, it may be significantly more challenging for plaintiffs to establish causation—and in particular, specific causation—than it is to establish foreseeability. To succeed in such a case, a plaintiff would need to establish several lines of causation:

- The plaintiff must link a specific change or event to anthropogenic climate change (e.g., sea-level rise or a flooding event)—i.e., climate change and extreme event attribution.

- The plaintiff must link a specific loss to that change or event (e.g., the cost of adaptation measures or residual losses that were not or could not be avoided through adaptation)—i.e., impact attribution.

- The plaintiff must link the defendant's conduct (i.e., release of GHG emissions) to anthropogenic climate change and identify the defendant's relative contribution to the harm incurred by the plaintiff—i.e., source attribution.

Regarding the first line of causation: proving that a specific change or event is caused by climate change will be easier for long-term changes such as mean temperature increases and sea-level rise. Linking a specific extreme weather event to climate change poses another test. The probabilistic approach to event attribution, whereby scientists quantify the extent to which anthropogenic climate change affected the probability of the event occurring, would likely be the best vehicle for establishing causation for the purposes of tort litigation.[34]

Even if the plaintiff is able to establish that a physical change or extreme event was caused by climate change, he or she must also establish the second and third lines of causation. The second causation challenge—establishing and quantifying the specific loss caused by the change or event—involves determining the extent to which the loss was caused by anthropogenic climate change as compared with other confounding factors. A probabilistic approach can also be used in impact attribution to generate this sort of information. However, to date, most impact attribution studies do not produce findings that are as quantitatively robust as studies conducted on extreme events due to the number of confounding factors that influence impacts such as public health outcomes. The third causation challenge—defining the defendant's relative contribution to the damage—is a matter of source attribution.

31. *Id.* at 280.
32. *See, e.g.*, Kysar, *supra* note 26, at 31; Michael Duffy, *Climate Change Causation: Harmonizing Tort Law and Scientific Probability*, 28 Temp. J. Sci. Tech. & Env't L. 185 (2009).
33. Kenneth S. Abraham, The Forms and Functions of Tort Law 124 (3d ed. 2007).
34. Myles Allen et al., *Scientific Challenges in the Attribution of Harm to Human Influence on Climate*, 155 U. Pa. L. Rev. 1385 (2007) (citing Myles Allen, *Liability for Climate Change,* 421 Nature 891, 891-92 (2003)); Dáithí A. Stone & Myles R. Allen, *The End-to-End Attribution Problem: From Emissions to Impacts,* 71 Climatic Change 303, 303-04 (2005).

IV. Future Directions in the Law and Science of Climate Attribution

Here, we discuss future directions in the law and science of climate change attribution, addressing questions such as how attribution science might better support policymaking, planning, and litigation.

A. *How Can Attribution Science Better Support Climate Law, Policy, and Planning?*

There are a variety of ways in which the scientific community could work toward supporting applications of attribution research: (i) continuing to lead the development of scientific knowledge and understanding by advancing detection and attribution research across the board; (ii) generating attribution findings at different confidence levels to better communicate uncertainty about the "upper bound" and "lower bound" of plausible anthropogenic influence on an observed change; (iii) communicating findings clearly and in an accessible format; (iv) engaging stakeholders; and (v) linking individual studies to other advancing research areas that help to flesh out the causal chain from emissions to impact.

1. Continue to Conduct Attribution Research on the Full Range of Climate Change Impacts With an Eye Toward Improving Confidence Levels and Certainty in Findings

The body of attribution research has grown considerably in recent years, increasing levels of confidence and certainty regarding a wide range of climate impacts at multiple political and geographical scales. So, in an important sense, the single most important thing the scientific community can do to support applications of attribution research is *more of the same*. Nevertheless, the scientific community could work with affected stakeholders to address the incomplete coverage of attribution science and identify priority areas for research. Granted, working with affected people to determine what variables to focus on in attribution studies could contribute to concerns about selection bias. As such, scientists may need to be cautious about any overarching statements made with respect to the body of attribution research.

2. Generate Findings at Different Confidence Levels

Attribution findings are often expressed in terms of probabilities and confidence levels. For example, a probabilistic event attribution study might find with > 90% confidence that anthropogenic climate change quadrupled the risk of a particular storm occurring. Depending on the application, it may be helpful for researchers to also discuss lower-bound, higher confidence estimates (e.g., > 95% confidence that anthropogenic climate change at least doubled the risk of that same storm occurring) or higher-bound, lower confidence estimates (e.g., > 80% confidence that anthropogenic climate change made the storm at least six times more likely). Lower-bound estimates with higher confidence levels would be more useful for applications where certainty in findings is needed, such as litigation. Upperbound estimates with lower confidence levels would be more useful in policy and planning applications where decisionmakers would benefit from understanding the potential extent of anthropogenic influence on an observed change.

3. Clearly Communicate Findings

It is helpful for the scientists conducting attribution research to present their findings in a clear and accessible fashion, to the extent practicable. Careful communication involves providing context for statements about uncertainty, bias, and limitations to help a non-scientific audience understand: (i) whether the level of uncertainty, bias, etc. is standard or unusual as compared with similar studies; and (ii) the effect of uncertainty and bias on the reliability and accuracy of the results. Scientists should also be careful not to overstate the novelty of this field—while attribution science is undergoing constant evolution, the vast majority of studies published in this field are based on well-established scientific techniques, carefully tested models, and detailed observational sets.

4. Engage With Stakeholders

Engagement is critical to successful communication, and to growing the impact of attribution research. Given the expertise about impacts that resides with stakeholders, deeper stakeholder engagement can also be expected to lead to scientific advances not only in attribution science for decisionmaking, but also for attribution science itself. For example, a stakeholder engagement process with water managers encouraged attribution scientists to focus on a broader set of event metric definitions, including the duration of rain events, in order to make their research more relevant for decisionmakers and sector experts.[35]

5. Link Individual Studies to Related Research to Help Flesh Out the Causal Chain From Emissions to Impact

Most attribution studies only focus on one part of the causal chain linking emissions and land use changes to impacts. To the extent that the scientists working on these studies are aware of related research, it would be helpful for them to explicitly discuss this research and explain how it ties into their own findings. Researchers and scientific organizations could also publish more synthesis reports

35. Julie A. Vano et al., *Hydroclimatic Extremes as Challenges for the Water Management Community: Lessons From Oroville Dam and Hurricane Harvey, in Explaining Extreme Events of 2017 From a Climate Perspective*, 100 Bull. Am. Metrological Soc'y (Special Supplement) S1 (2019).

linking individual studies and explaining the extent to which these studies, in aggregate, can support claims of end-to-end attribution. Where possible, it would be helpful to harmonize the scope and scale of connected studies such that the quantitative analyses conducted in one study can flow through and inform the quantitative analysis in the subsequent study, with the goal being to develop robust, quantitative findings across a larger section of the causal chain. More fundamentally, further standardization of attribution research—ranging from the selection of topics to study, to the metrics used, and the data and models brought to bear—will support cross-comparison, evaluation, and scaling up of findings across studies.

B. *How Might Judges and Litigants Utilize Attribution Science in the Courtroom?*

1. Standing and Justiciability

The single greatest obstacle to the effective utilization of attribution science in the courtroom is the fact that climate cases raising complex attribution issues may be dismissed or decided without a trial, meaning that their scientific bases may never be fully assessed and adjudicated. One of the main reasons for dismissal is lack of standing. Some courts have recognized that the questions implicated in the standing analysis are heavily fact-dependent and tend to overlap with the merits of the case.[36] But other courts have denied standing based on a cursory assessment of these scientific questions, finding without trial that the causal connection between emissions and injury is too attenuated.[37] Standing claims involving disputed facts should be addressed after discovery, when all issues are fully briefed and all evidence is submitted.[38]

Some scholars have also recommended specific analytical techniques that are uniquely well-suited for assessing standing claims in cases involving climate change-related claims. For example, scholars have recommended that courts recognize that the risk of harm is itself an injury that can provide the basis for standing.[39] Another approach could be to allow "fractional standing" for probabilistic injuries.[40] According to one commentator, a "fractional injury" is "one that, if manifest in one individual, would be insufficient to grant standing" but if "multiple individuals experience this injury and band together to demand relief . . . then their collective grievance would be sufficient to merit standing."[41] Fractional standing involves looking at the probability of the harm, the severity of the harm, and the number of people at risk and determining whether the aggregate harm is sufficient to grant standing.[42] The U.S. Court of Appeals for the District of Columbia (D.C.) Circuit implicitly endorsed this approach in *Natural Resources Defense Council v. EPA*.[43]

2. Factual and Proximate Causation

a. Defining Parties' Contributions to GHGs

The first step in determining whether a party is a legally relevant cause of damages associated with climate change is to define that party's contribution to increases in atmospheric GHG concentrations. Some form of quantification is necessary to establish both factual cause and proximate cause. Yet, defining a party's GHG contribution is not as straightforward as one might like. There may be data gaps that preclude accurate quantification. Even where adequate data exists, there are inevitably analytical questions that must be answered, such as which emissions accounting approach to use—territorial, consumption-based, or extraction-based—and how to account for historical as compared with present (and possibly even future) emissions. While there is no strict requirement that different courts addressing different types of legal claims, in different jurisdictions, use the same accounting methods to impose responsibility on entities, these discrepancies can raise concerns about fairness, justice, and the efficiency of the judicial system.

Further, other types of information are relevant to the analysis of proximate cause and supplement attribution data. Some of the normative considerations relevant to the proximate cause inquiry include the extent to which the company profited from the production and eventual use of fossil fuels, whether the company knew that it was producing and selling a harmful product, and whether the company engaged in unethical activities such as the obstruction of climate change science.

b. Establishing Causal Connections to Impacts

Litigants and courts should be aware of both the strengths and limitations of attribution science when framing and analyzing casual arguments. Plaintiffs may prove most successful where they base their claims on impacts which can be attributed to anthropogenic climate change with high confidence—such as sea-level rise, melting snowpack, increases in average temperatures and extreme heat, and ocean acidification—or where they rely on expert reports and peer-reviewed attribution studies and avoid making causal inferences even for those impacts for which there is

36. Juliana v. United States, 217 F. Supp. 3d 1224, 1242-48, 46 ELR 20175 (D. Or. 2016).
37. *See, e.g.*, Native Vill. of Kivalina v. Exxon Mobil Corp., 663 F. Supp. 2d 863, 880, 39 ELR 20236 (N.D. Cal. 2009).
38. Note, *Causation in Environmental Law: Lessons From Toxic Torts*, 128 Harv. L. Rev. 2256, 2270-71 (2015); Luke Meier, *Using Tort Law to Understand the Causation Prong of Standing*, 80 Fordham L. Rev. 1241, 1265 (2011).
39. *See, e.g.*, F. Andrew Hessick, *Probabilistic Standing*, 106 Nw. U. L. Rev. 55, 67-68 (2012); Albert Lin, *The Unifying Role of Harm in Environmental Law*, 3 Wis. L. Rev. 897, 911 (2006); Cass Sunstein, *Standing Injuries*, 1993 Sup. Ct. Rev. 37 (1993).
40. Daniel E. Rauch, *Fractional Standing,* 33 Yale J. on Reg. 281 (2016).
41. *Id.* at 282.
42. *Id.* at 290-91.
43. 464 F.3d 1 (D.C. Cir. 2006).

a very robust connection to anthropogenic climate change. Judges, meanwhile, should be mindful of the fact that there are different levels of confidence for different impacts, pay close attention to the evidence submitted, and should not dismiss claims based on generalized conclusions about the uncertainty of the science. Judges should also be aware that, when translating global or regional impacts to specific injuries, it may be necessary to accept causal inferences.

3. Proving and Defending Against Obligations and Redressability

While there is some precedent affirming national obligations in other jurisdictions,[44] no U.S. court has yet found that the federal government is bound to any particular level of climate ambition. Even still, source attribution data is constantly improving and estimates of carbon budgets are constantly being revised in light of new emissions data, so it will be important for litigants and courts to rely on the most recent data in framing carbon budgets. Attribution science could be used to define more specific obligations for national governments. For example, rather than mandating a government achieve a specific target on a specific date, a court could require the government to establish and periodically update its target based on the best available science.

In establishing obligations for private actors, one critical question will be how to allocate liability and damages among multiple companies. Arguably, imposing several liability based on the party's proportionate contribution to GHG increases is the approach that best reflects the party's "true" contribution to climate change impacts. A market-share approach—apportioning liability among fossil fuel companies based on their share of fossil fuel sales—would also accomplish this if the "market share" were defined as the share of GHG emissions. In contrast, imposing joint and several liability may result in overestimation of a party's contributions to the injury. However, there may be compelling reasons to impose joint and several liability in certain contexts.

V. Conclusion

The recent waves of cases brought against national and subnational governments, seeking increased mitigation ambition, and against fossil fuel and energy companies, seeking compensation or abatement funds for the costs of adaptation, have made the relationship between the science and law of climate change attribution all the more salient. But there are significant scientific issues that remain to be clarified, for law and policy purposes, and it may well be that litigation provides the forum for achieving that clarity.

44. *See* Urgenda Foundation v. Kingdom of the Netherlands, Hoge Raad, ECLI:NL:HR:2019:2007 (Dec. 20, 2019) (English translation available at http://blogs2.law.columbia.edu/climate-change-litigation/wpcontent/uploads/sites/16/non-us-case-documents/2020/20200113_2015-HAZA-C09004566 89_judgment.pdf).