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Constructing the causal chain: attribution science in polluter pays climate litigation

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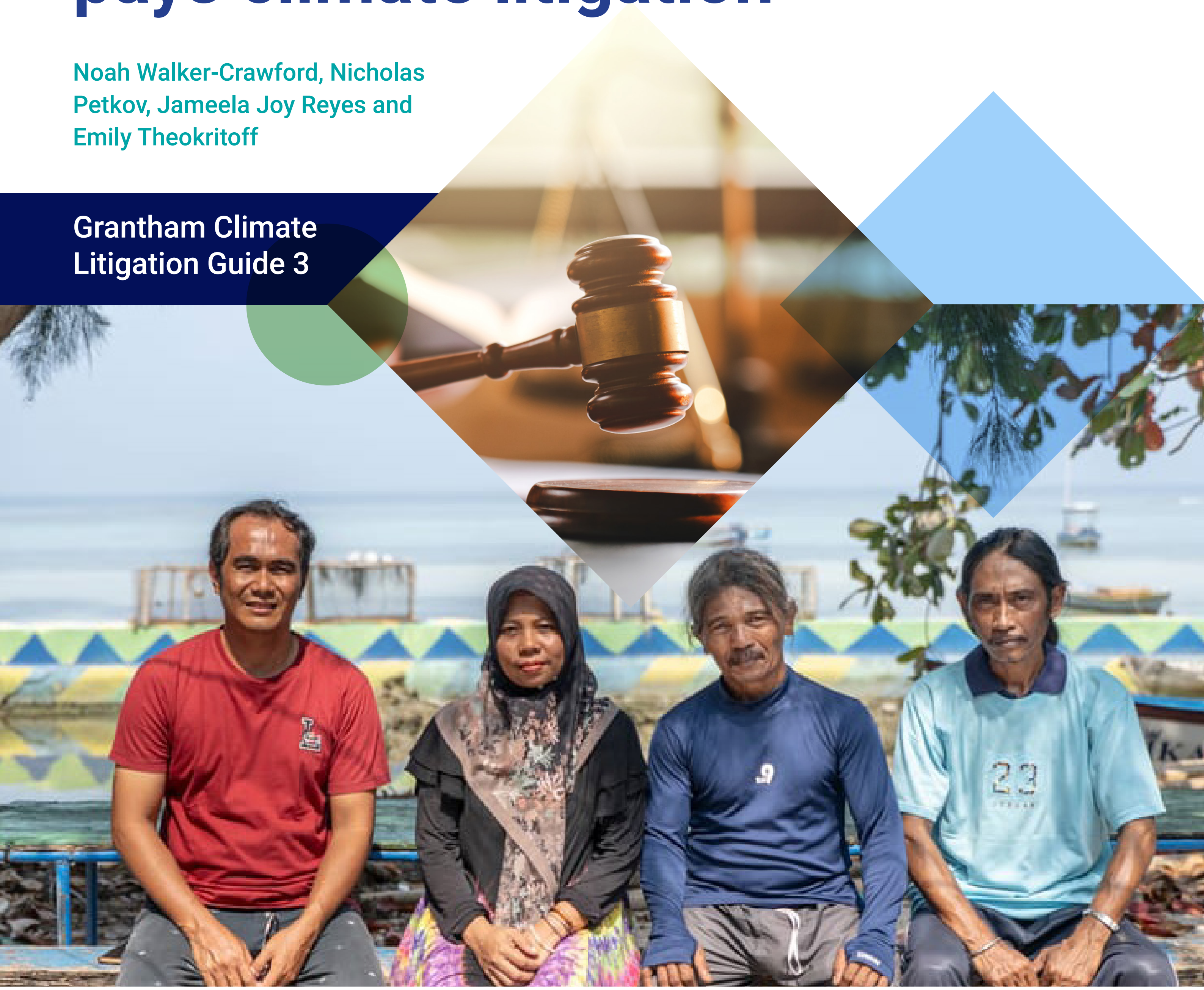
Grantham Climate Litigation Guide 3



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About this guide

This guide is the third in the Grantham Climate Litigation Guides series. These guides are a collaboration between the Grantham Research Institute at LSE and the Grantham Institute at Imperial College London. The series is designed to provide informed guidance on the use of climate science and evidence in legal and policy contexts in concise, non-technical language. Further guides will be published in 2026.

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Contents

Summary points

- In ‘polluter pays’ litigation, part of a rapidly expanding landscape of climate litigation targeting state and non-state actors, claimants must establish a causal relationship between a defendant’s greenhouse gas emissions and a specific incidence of past or future harm.
- Understanding and presenting this relationship to legal audiences can be complex, involving multiple disciplines and differing legal tests. Attribution science, the field of climate science that seeks to understand the influence of anthropogenic emissions on the past and future climate, is increasingly used to support compensation claims from major emitters for climate-induced damage in these cases.
- Rapid developments in attribution science mean that researchers can now quantify the emissions attributable to individual companies, assess how climate change has altered specific weather events and estimate the resulting damages.
- However, translating these scientific findings into legally sufficient evidence is challenging. Scientific and legal standards of proof differ, causation tests vary across jurisdictions, and the evidence needed to substantiate claims is diverse and technically complex.
- The causal arguments made in polluter pays cases can be understood in terms of a ‘causal chain’, an evidentiary framework that links emissions to harm. This chain can be divided into three ‘causal links’: focusing on damage or risk of damage, physical hazard and emissions. Three important European polluter pays cases highlight how this causal chain has been demonstrated by claimants: *Luciano Lliuya v. RWE AG*, *Asmania et al. v. Holcim* and *Hugues Falys v. TotalEnergies*.
- Polluter pays litigation cases face ongoing challenges, including the difficulty of meeting evidentiary standards, uncertainty around the adequacy of existing causation tests to account for climate-related harm and uneven data availability that may create disproportionate barriers for claimants in the Global South.
- Despite these barriers, polluter pays litigation has seen some court decisions favourable to claimants. Furthermore, several developments in the area – including advances in end-to-end attribution methodology, the potential extension of claims to the financial sector, and moves towards greater communication between scientific and legal communities about their different needs and limitations – may lead to more polluter pays claims in the future.

Introduction

This guide examines how evidence from attribution science is constructed and presented in courts to seek compensation from major greenhouse gas emitters for climate-related harm. Focusing on 'polluter pays' cases specifically, it explores the scientific and legal foundations of the evidentiary arguments used by claimants, examining concepts such as causation in law and standards of proof, as well as some of the areas in which scientific and legal conversations on these issues overlap.

Climate litigation, causal chains and polluter pays claims

Over the past two decades, attribution science has transformed our ability to connect greenhouse gas emissions to their consequences. Researchers can now quantify the emissions attributable to individual companies, assess how climate change has altered specific weather events and estimate the resulting damages. These scientific capabilities are increasingly being brought into courtrooms. In 'polluter pays' climate litigation, claimants draw on attribution science to seek compensation from major emitters for climate-related harm. This guide examines how evidence from attribution science is constructed and presented in polluter pays litigation.

Polluter pays cases form part of a broader and rapidly expanding landscape of climate litigation. To date, nearly 3,000 climate-related cases have been filed in over 60 countries, targeting both state and non-state actors (Setzer and Higham, 2025). These cases vary in approach: some challenge government policy ambition and implementation, while others target corporate actors.

- For an overview of the different case strategies and how scientific evidence is used across them, see Grantham Climate Litigation Guide 1.
- For an analysis of how corporate defendants have responded to these claims, see Grantham Climate Litigation Guide 2.

Polluter pays cases require claimants to establish a causal relationship between a defendant's emissions and a specific past or future harm. Named after the widely recognised principle that those who produce pollution should bear the costs of managing it (Ward and Hicks, 2022), these cases typically rely on tort-based causes of action to seek compensation or the funding of adaptation measures.[1] The causal relationship at the heart of these claims is complex: linking an individual emitter to a localised harm requires navigating multiple scientific disciplines and legal tests. As documented in the second guide in this series, defendants have challenged these causal arguments on multiple grounds, including the sufficiency of the underlying science and the appropriateness of existing legal tests for establishing causation in the climate context.

The growth of polluter pays litigation has occurred alongside rapid developments in attribution science. Over the past decade, attribution methods have advanced significantly, with the field recognised as a "broadly accepted tool in the scientific community" (*Nature Climate Change*, 2024). At the same time, recent legal developments have clarified that, in principle, major emitters can be held liable for their contribution to climate-related harm. However, translating scientific findings into legally sufficient evidence remains a challenge. Scientific and legal standards of proof differ, causation tests vary across jurisdictions, and the evidence required to substantiate these claims is diverse and technically complex. It is these intersections between science and law which we explore throughout this guide.

In the guide, we deconstruct the 'causal chain' that underpins polluter pays claims, examining how claimants assemble and present evidence to link emitters to specific climate-related harm. Our analysis primarily focuses on the evidentiary arguments advanced by claimants, rather than providing a comprehensive account of how defendants or courts have engaged with these arguments (for this account, see the second guide in the series). Where relevant, we note challenges and limitations in the arguments put forward. To support understanding, we pair analysis of each stage of the causal chain with a 'science explainer' that clarifies the key scientific concepts involved, providing deeper insight into the attribution science, its methodologies and challenges.

[1] To date, polluter pays cases have only been filed against corporate defendants; however, the category does not preclude actions towards other actors.

Structure of the guide

The guide is divided into three main parts:

- Part 1 presents an overview of the scientific and legal foundations required to understand claimants' arguments in polluter pays litigation. It introduces attribution science as a scientific discipline, outlines the specific legal bases in claims filed to date, and discusses some of the issues raised at this intersection of science and law, including causation and standards of proof.
- Part 2 introduces the concept of a causal chain, outlining how it has been used in other contexts and how it is conceptualised in this guide. The section then outlines the three 'causal links' that claimants use to link a high-emitter to climate-related harm, providing insight into the evidentiary arguments made. Each link is paired with a 'science explainer'.
- Part 3 outlines how causal chains and arguments are advanced by the claimants in three different European polluter pays case studies, providing more detail about the specific claims and evidence used.

The guide concludes with a reflection on some of the key challenges in polluter pays litigation and developments that may open new possibilities for claimants in the future.

Box 1. Research methods and choice of cases

We conducted an in-depth study of 11 polluter pays legal cases across six jurisdictions: Belgium, Germany, South Korea, Switzerland, the UK and the US. We carried out a systemic textual analysis to examine the types of scientific evidence used and considered by the legal parties and judges. We reviewed all publicly available case documents up to April 2026, beginning with the initial pleading or summons and continuing to the most recent accessible document, brief or court decision. We used DeepL translation software for documents not written in English.

At the time of publication, more than 80 polluter pays cases have been filed. We do not provide a systematic overview of the entire polluter pays category; instead, we target our analysis on cases that are identified as particularly influential, unique or developed. Some cases referred to may fall under other strategies identified by Setzer and Higham in their most recent *Global Trends in Climate Change Litigation* report (2025), such as corporate framework cases that seek injunctions from the court that restrict future emissions (e.g. *Asmania et al. v Holcim*). This reflects the diverse range of arguments made in some claims.

Due to the small number and diverse nature of cases filed to date, our analysis is not a prescriptive overview of how causal chain evidence should be used. Instead, we offer reflections on some instances where this evidence has been introduced. Our assessment may differ from the views of those directly involved in the cases. Our aim is to provide an independent overview of key scientific evidence used across these diverse cases. In the Appendix, we list the cases studied and their legal bases.

Part 1: Scientific and legal foundations

Polluter pays litigation is grounded in both scientific and legal foundations. Claimants must rely on scientific expertise to establish a causal link between specific emitters and climate-related risks and impacts, while simultaneously drawing on legal principles and frameworks to translate these scientific insights into actionable legal claims. In this section, we outline the foundational concepts necessary to understand this complex intersection between science and law.

Attribution science

Attribution science evaluates general trends or specific events across different aspects of the Earth's climate system. It provides key evidence for polluter pays cases. The term 'attribution' refers to "the process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence" (Intergovernmental Panel on Climate Change [IPCC], 2023). In its early phases, from the 1970s through to early 2000s, attribution science mainly focused on attributing detected changes in global temperature to human activity, providing the evidentiary basis for climate policy and underpinning early IPCC reports.

The methodology used in these early studies exploring the links between global temperature and human activity is known as **detection and attribution**. Climate models were used to compare observed temperature changes against what would be expected from natural variability alone, isolating a statistical fingerprint of human influence (Stott and Mitchell, 2021). In other words, this methodology is used to identify what the world would have been like without human influence and to compare this with what in fact happened. As its methods matured, attribution science produced increasingly confident conclusions. The IPCC's *Third Assessment Report*, for example, concluded that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" (IPCC, 2001). During this early phase, attribution science also began drawing conclusions about longer-term trends such as sea level rise, the loss of land ice and changes in precipitation patterns.

In the early 2000s, researchers in the field began examining the causes of specific extreme weather events (Union of Concerned Scientists [UCS], 2025). Extreme event attribution uses climate models and weather observations to compare present day weather events with a counterfactual set at pre-industrial temperature levels. The first event attribution study analysed the 2003 heatwave in Europe, concluding that human influence had at least doubled the risk of such extreme temperatures (Stott et al., 2004). In the years since, rigorous methodologies have been developed to enable scientists to quantify if and how climate change has altered the likelihood or intensity of weather events (van Oldenborgh et al., 2021). Scientists can even provide rapid analysis of the influence of climate change in the immediate aftermath of an event (World Weather Attribution, n.d.). Attribution science that focuses on extreme weather events and longer-term trends such as sea level rise is known as **physical hazard attribution**.[2]

Other strands of attribution science have developed, two of which are particularly relevant to polluter pays litigation: source attribution and impact attribution. Source attribution emerged in the 2010s, extending the field to consider the role of specific greenhouse gas emitters. Originating with a paper tracing anthropogenic emissions to fossil fuel and cement producers (Heede, 2013), it is now underpinned by a large database of historical production data, used to quantify the emissions attributable to the world's largest emitters (Carbon Majors, n.d.). A more recent strand to emerge from within attribution science is impact attribution, which examines the consequences of climate events at a societal level, including the economic costs, health impacts and other damages.

Together, these strands of attribution science research have been used to demonstrate a chain of causation linking a specific emitter's contribution to a specific harm. We will discuss source attribution, physical hazard attribution and impact attribution in further detail in Part 2.

Attribution science must satisfy legal standards and thresholds for it to be used in a legal context. At least in part, this requires claimants relying on attribution science to examine the scientific sources that courts have engaged with and considered in climate litigation cases. As discussed in the first guide in this

[2] 'Physical event attribution' is often what is being referred to when the general term 'attribution science' is used.

series, courts broadly favour evidence that has undergone thorough and transparent peer review, which they consider to represent scientific consensus. For instance, courts deciding climate litigation cases have viewed reports from the IPCC, the United Nations body for assessing the science related to climate change, as particularly persuasive evidence. The IPCC publishes Assessment Reports every seven to nine years on the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. It has become a central pillar in climate litigation, shaping both parties' and courts' reasoning (International Court of Justice [ICJ], 2025; Zhu and Fan, 2024; see also Walker-Crawford et al., 2026).

While conclusions from attribution science are cited in the IPCC reports, these conclusions are not always able to comprehensively address legal questions around causation raised in individual claims. This is because the IPCC synthesises the current state of climate science, presenting broader conclusions about events, impacts and the role of human influence on the climate. Polluter pays litigation, by contrast, tends to focus on specific events or localised impacts, a level of granularity rarely provided by the IPCC reports. Furthermore, given the time gap between the assessment reports (between five and seven years), the most recent scientific research will often be absent from the IPCC reports. In practice, claimants in climate litigation have supported their claims, not only by citing material from the IPCC, but also by submitting or citing individual studies that address specific events and impacts directly. For greater detail on evidence in climate litigation, see the first guide in this series.

Legal basis for polluter pays claims

Since 2015, more than 80 polluter pays cases have been filed against major industrial emitters (Setzer and Higham, 2025). However, to date, none of these cases have succeeded on both factual and legal grounds. These private law-based actions have been filed in a variety of jurisdictions, including Belgium, Germany, South Korea, Switzerland, UK and US. As illustrated in the Appendix, the legal grounds of different claims vary greatly. In *Lliuya v. RWE*, the claimants creatively applied a basic property interference provision to a transboundary harm.[3] In *Asmania v. Holcim*, the claimants use a provision protecting personality rights to give effect to the claimant's fundamental rights in the context of climate change (Reyes and Burri, 2024). This provision is most often used against invasive journalism practices (ibid.).

Among the US polluter pays cases, multiple state law legal theories have been pursued, including public nuisance, private nuisance, negligence, trespass, failure to warn and design defect (Burger et al., 2020). These diverse actions show that there is no unified approach to bringing a polluter pays case. Importantly, despite these differences, the cases follow a similar structure in their arguments and use of evidence.

The main reason for the diversity in causes of action is that none of the mentioned jurisdictions have a specialised 'climate tort' or provision that claimants can use to request compensation for their climate-related losses. Therefore, those wishing to seek compensation through legal means have used various existing doctrines and laws that may allow their claim. This reflects the emerging nature of these claims and the limited degree to which climate issues have been systematically addressed across legal systems.

Comparing how different polluter pays cases have been brought can offer useful insights into the suitability of existing legal systems for accounting for climate-related harm. However, there are limits to these comparisons: the range of jurisdictions used to file these cases means that legal systems and traditions differ significantly across the category. The diversity in causes of action (see Appendix) means that different legal tests apply, each with their own nuances and requirements. Furthermore, given that many cases are still ongoing, it is difficult to assess the merits of specific approaches, legal actions or evidentiary strategies.

There have been some notable recent legal developments in the polluter pays category, notably the case of *Lliuya v. RWE*. In May 2025, the Higher Regional Court of Hamm in Germany confirmed that the property interference claim was legally viable, and that one specific emitter can, in principle, be held liable for their contribution to climate change impacts.[4] Two further European polluter pays cases have since been deemed admissible.[5] In December 2025, the Cantonal Court of Zug, Switzerland allowed the case

[3] See Claim: https://cdn.climatepolicyradar.org/navigator/DEU/2015/luciano-lliuya-v-rwe-ag_34eb9612efb0ecf2599a65f6fa6d46f6.pdf
[4] See Judgment: https://cdn.climatepolicyradar.org/navigator/DEU/2015/luciano-lliuya-v-rwe-ag_e585fec2553b5e2374b8a576e43d07ce.pdf
[5] Admissibility refers to the threshold a claim must meet for a court to agree to hear it.

of *Asmania v. Holcim* to proceed to the next stage, where facts and arguments can be considered.[6] In March 2026, the Commercial Court of Tournai, Belgium confirmed its jurisdiction in *Falys v. TotalEnergies* and declared the action admissible. The court paused a decision on the merits of the case pending the outcome of a parallel case in France.[7] In the US, cases have largely centred on procedural disputes around jurisdiction and venue, with state courts reaching differing outcomes on whether cases can proceed to trial (Setzer and Higham, 2025). Some are nonetheless advancing: for instance, *City and County of Honolulu v. Sunoco LP*, is now in a pre-trial phase and moving towards trial (Center for Climate Integrity, 2026).

Elsewhere, the law may be evolving to accept novel climate torts, meaning that private law systems may directly engage with the issues of climate change. Though not a polluter pays case, in *Smith v Fonterra*[8] the claimant argued for a new tort for environmental damage in the context of seeking emissions reductions obligations for a list of major emitters in New Zealand. Here, the court rejected defendant's arguments that the claim was not possible, finding that there was room for the law to evolve.[9] This case is scheduled to proceed to trial in April 2027 (Climate Rights Database, 2025), though proposed New Zealand legislation that could retrospectively extinguish such claims serves as a reminder that the future of climate tort litigation remains contested (Bookman, 2026)

Despite some legal successes, there remain obstacles for claimants in litigation against major emitters, including the legal assessment of causation. In general terms, causation involves assessing the link between the claimant's harm and the defendant's action and can be divided into two distinct aspects: factual and legal. Factual causation asks whether the defendant caused the harm as a **matter of fact**; legal causation is concerned with whether it is **legally appropriate** to hold the defendant liable for the alleged harm. The specific terms and language used varies greatly by jurisdiction.

The traditional approach to factual causation, in legal systems where cases have been filed, is the 'but for' or '*conditio sine qua non*' test (Moore, 2024). This test involves creating a counterfactual where the court asks, 'without the actions of the defendant, would the alleged harm have occurred?' This simple test can face issues where multiple factors contribute to a harm. In these cases, it may be difficult to isolate the role of any single contribution. A related difficulty arises with 'concurrent' causes, where no single cause is sufficient to produce the outcome on its own, but each forms part of a larger set of causes that together produce it.

In the climate context, the cumulative nature of harm from greenhouse gas emissions amplifies these challenges. While any individual contribution to total global emissions may appear small, the aggregate effect can be significant. As a result, it is not straightforward to argue that a major emitter's contribution to a particular harm satisfies the but-for test.

Whether the but-for test can be satisfied in polluter pays climate cases is an open question in both the academic literature and the jurisprudence. Some scholars argue that attribution science now provides sufficient evidence to meet this standard (Stuart-Smith et al., 2021). Others contend that the cumulative and multi-causal nature of climate harm makes it fundamentally difficult for any single emitter's contribution to satisfy a strict counterfactual test (Burman, 2022). Courts that have engaged with this question have reached different conclusions, and the issue is far from settled. Moreover, alternative causation tests exist beyond the but-for test and may be relevant in some jurisdictions and circumstances. These tests are discussed below.

Evidence provided to support causation tests must prove the facts in question to a sufficient level of certainty, known as a 'standard of proof'. A standard of proof is the required level of certainty and the degree of evidence necessary to establish proof in a legal proceeding. The standard applied and the process by which evidence is assessed varies across jurisdictions. In common law jurisdictions, such as US and UK, the standard of proof in civil cases generally requires that a fact is proven to be 'more likely true than false', with a probability exceeding 50% (Clermont and Sherwin, 2002). However, in the civil law context, such as continental Europe, the standard of proof is not focused on probability, but on the 'personal rational conviction' (Verkerk, 2009) of the deciding judge that the fact has been proven. For

[6] See Decision: https://cdn.climatepolicyradar.org/navigator/CHE/2022/asmania-et-al-vs-holcim_fa1e6eca8a627b41f312a12b18388f60.pdf
[7] See Order: https://cdn.climatepolicyradar.org/navigator/BEL/2024/hugues-falys-fian-greenpeace-ligue-des-droits-humains-v-totalenergies-the-farmer-case_353654896dbabcb095ed5dda92afd8bc.pdf
[8] See Complaint: https://www.climatecasechart.com/document/smith-v-fonterra-co-operative-group-limited_33b2
[9] See Judgment: https://cdn.climatepolicyradar.org/navigator/NZL/2020/smith-v-fonterra-co-operative-group-limited_8ba7b9e81ceb7f91db9f8e7dc2fec593.pdf

example, in Germany, the Code of Civil Procedure states that the court is to decide "at its discretion and conviction" whether an allegation as to fact is to be deemed true or untrue (German Code of Civil Procedure S.286). This standard is not clearly quantified in the way the common law test is. Although not demanding 'absolute certainty', it is understood to be clearly beyond the 'balance of probabilities' (Steel, 2015).

Legal developments and the science–law intersection

With so few polluter pays cases filed, issues around causation and proof must be understood within the context of how the law deals with change. Given the novel issues presented by climate change, it is difficult for scholars to draw conclusions about the legal grounds for existing cases across jurisdictions. In the academic literature, scholars have highlighted the inadequacies of private law regimes to account for climate harm (Burman, 2022; Minnerop and Otto, 2020). However, developments over the past century in other areas of law have led to the traditional position on causation being relaxed in certain instances, particularly where there have been evidentiary or practical arguments to do so. This has led some to characterise causation in the law as an inquiry involving 'common sense' (Hart and Honore, 1985).

In the UK context, this is illustrated by the case of *Fairchild v. Glenhaven Funeral Services Ltd*,[10] a tort liability case in which the court was unable to establish which of the claimant's many employers had caused his mesothelioma through asbestos exposure. The court held that in cases of such scientific uncertainty, the strict but-for standard could be relaxed, such that a defendant can be found liable if the claimant could show they materiality contributed to the harm.

Beyond material contribution, other alternative causation standards have been applied or discussed in analogous multi-causal contexts. These include market share liability, where damages are apportioned according to a defendant's share of the relevant activity (as applied in *Sindell v. Abbott Laboratories*[11] in the US), and the NESS (necessary element of a sufficient set) test, which asks whether a defendant's conduct was a necessary element within a set of conditions that were together sufficient to cause the harm (Burman, 2022). Similar relaxations of strict causation standards have occurred across jurisdictions, and scholars have discussed their potential applicability to climate cases (Burger et al., 2020).

Other sources of legal authority have engaged with the question of whether causation tests appropriately capture the complex nature of climate change. In 2022, the Philippines Commission on Human Rights in its National Inquiry on Climate Change, in its recommendations to the judiciary, argued that in many jurisdictions, courts using stringent standards of legal causation "disregards the work of climate and attribution science and causes more climate injustice".[12] Furthermore, in its 2025 Advisory Opinion on the Obligations of States in respect of Climate Change, the International Court of Justice found that while the link between the acts of states and the harm arising from climate change is more tenuous than in the case of local source of pollution, this does not mean the identification of a causal link is impossible, and must be considered on a case-by-case basis (ICJ, 2025).

Questions around standards of proof operate at a clear intersection between science and law. As discussed, the standard applied in civil law systems is often higher than that used in common law systems. However, both legal standards are significantly lower than the confidence thresholds typically applied in scientific research. In many scientific disciplines, findings are conventionally considered statistically significant at a 95% confidence level; the IPCC uses calibrated uncertainty language that reserves terms such as 'very likely' for conclusions with at least 90% probability (IPCC, 2023). By contrast, the common law 'balance of probabilities' standard requires only that a fact is more likely true than false (exceeding 50%), and civil law systems, while sometimes demanding a higher degree of judicial conviction, still do not approach the thresholds common in scientific practice. This gap reflects different institutional purposes, rather than a deficiency on either side: scientific inquiry is oriented toward building robust, reproducible knowledge over time, whereas courts must resolve specific disputes on available evidence within finite proceedings. As Marjanac and Patton (2017) have observed, legal and public institutions do not adopt the same rigorous standards as science when drawing conclusions about cause and effect. It has even been suggested that the IPCC adopt the category 'more likely than not' in their reports to better align with legal standards of proof (Lloyd et al., 2019). While this is not yet common practice, it raises

[10] [2002] UKHL 22. See Judgment: https://www.bailii.org/uk/cases/UKHL/2002/22.html
[11] [1980] 26 Cal. 3d 588. See Opinion: https://law.justia.com/cases/california/supreme-court/3d/26/588.html
[12] See the NICC Report: https://essc.org.ph/content/wp-content/uploads/2024/05/National-Inquiry-on-Climate-Change-Report-NICC_CHRP_2022.pdf

important questions about whether science should adapt its methods of communication to the legal and public institutions it seeks to inform.

The interaction between different scientific and legal standards raises fundamental questions about how gaps between the two fields can be bridged. The rapid development of attribution science in recent decades linking emissions to climate harm has led some to conclude that science is “no longer an obstacle to the justiciability of climate liability claims” (Callahan and Mankin, 2025). On this view, the difficulties surrounding causation in climate litigation are not primarily a product of scientific limitation, but of legal standards that have not yet evolved to accommodate what attribution science can now show (Burman, 2022). In this context, regulators, legal practitioners, judges, legislators and researchers should work to develop more appropriate tests and evidentiary standards. Others, however, note that significant scientific uncertainties remain, particularly around specific causation at the individual claimant level. As documented in the second guide in this series, defendants have challenged the rigour and applicability of attribution science in legal proceedings. What is clear is that the relationship between legal and scientific standards will continue to shape the prospects for polluter pays claims.

In practice, the scientific evidence underpinning polluter pays claims faces its own challenges, including gaps in data availability, uneven geographical coverage of attribution studies and the difficulty of applying broad scientific conclusions to the specific circumstances of individual claims. At the same time, rapidly developing methodologies may offer new possibilities for claimants. These scientific challenges and opportunities are explored in detail in Part 2.

Part 2. Causal chains in polluter pays litigation

What is a causal chain?

A causal chain is a helpful conceptual framework for understanding the dynamics of climate change, providing an approach for linking greenhouse gas emissions to climate impacts experienced by individuals via a chain of causal factors. In effect, a causal chain is a sequence of linked events or actions, where each linked act causes the next, ultimately connecting an initial act to an outcome. Rather than one cause producing one effect directly, the term causal chain points to a more indirect causal relationship. Specific climate-related harm occurs at the individual level, arising from physical climate hazards, which is intensified by the greenhouse effect, itself driven by the accumulation of emissions in the atmosphere.

The term 'causal chain' is widely used across disciplines to describe complex causal processes. It has been employed in literature on issues of causality in climate litigation (Krakau, 2025; Otto et al., 2022) and climate science more broadly (Prather et al., 2009). The concept has also featured prominently in other contexts with complex intersections between scientific and legal causation. Notably, these issues arose in 'toxic tort' litigation involving harmful exposure to defective pharmaceuticals or asbestos. There, as in climate cases, harm cannot be attributed to a single cause, but must instead be established through a chain of contributing factors (Callahan, 1991; Jones, 2011)

Significantly, in the polluter pays case studies examined in this guide, the causal chain term has been employed by claimants and courts alike,[13] suggesting that it has acquired a degree of shared meaning across the litigation process. Other similar language used includes 'causal relationship', 'causal connection' and 'causal link'.

In this guide, we use the term 'causal chain' as a conceptual device to analyse how evidence is framed and presented in polluter pays climate litigation. We show that causal chains can be understood as an analytical concept with two distinct dimensions. First, there is the factual evidentiary pathway that connects greenhouse gas emitters to the past or future harm suffered by claimants. Second, parties strategically construct a case narrative that frames that connection in legally recognisable terms. Together, these dimensions enable us to examine how parties assemble and present evidence in polluter pays litigation.

How the connection between a claimant's harm and a defendant's actions is presented in legal arguments does not depend solely on the scientific basis for the causal links. In practice, claimants present causal chains to the court in a condensed format, which makes the broad scientific case for the link accessible and intelligible to legal audiences. This conception of the causal chain does not intend to reflect every detail of the causal connection, but instead is used as a structured representation for legal audiences. Causal chains are communication devices. In the complex systems linking greenhouse gas emitters to those who suffer climate-related harm, causal chains help organise events into a factual narrative that assigns responsibility.

We define a causal chain as "an evidentiary model of cause and effect, comprised of a set of relationships (causal links), that functions to link emitters to those experiencing climate-related harm." The causal chain concept is dynamic and fluid, with a wide variety of applications in litigation and beyond. As such, the definition offered here is illustrative rather than exhaustive, and certain components are necessarily open-ended. To illustrate how claimants have shown the links between emissions and harm in polluter pays litigation, we use the term both in the factual and the broad narrative sense.

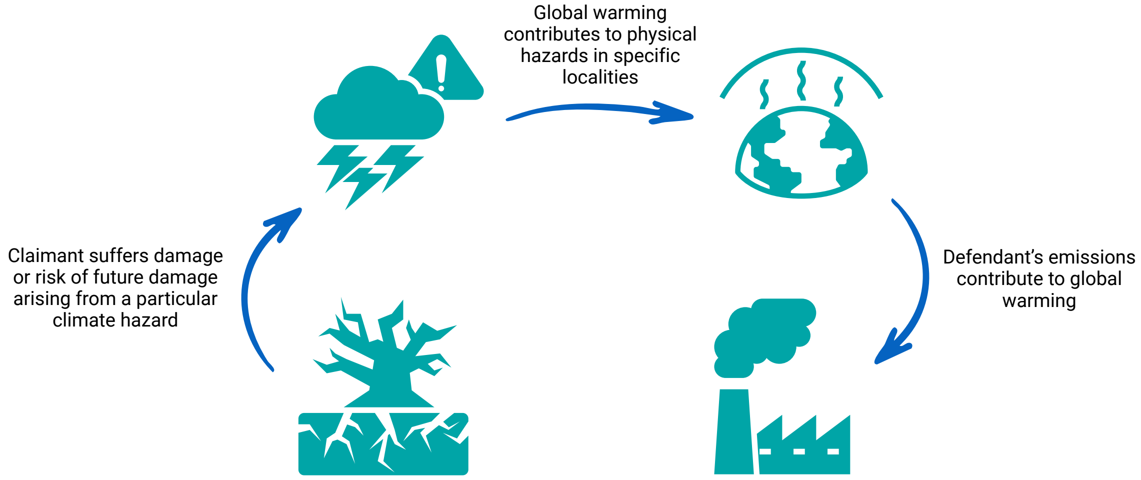
Figure 2.1 provides a representation of the causal chain used by claimants in polluter pays litigation. The diagram divides the causal links between a claimant and a major emitter into three broad stages:

- Specific damage or risk of damage to the claimant is linked to physical hazards
- Those physical hazards are linked to anthropogenic climate chains
- Climate change is linked to emissions attributable to specific defendants

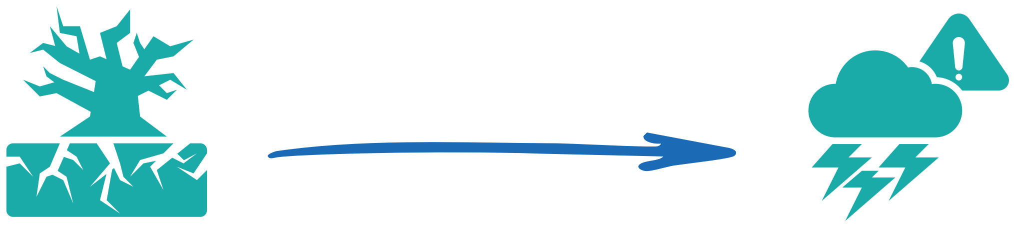
[13] For example, the term 'causal chain' or 'chain of causation' is used by claimants in *Lliuya v. RWE*, *Leon v. Exxon*, *Asmania v. Holcim* and *Falys v. TotalEnergies*. It is used by the courts in *Lliuya v. RWE* and *Asmania v. Holcim*.

This three-step structure is not the only way the causal chain can be divided; other framings are possible and may be more appropriate depending on the jurisdiction, legal context and the specific claim.

Figure 2.1. General causal chains diagram



Causal link 1: specific harm to climate hazard



In the first causal link, claimants connect a specific damage or risk of future damage to a climate-related physical hazard, such as a heatwave, storm or sea level rise. To do this, the claimant must demonstrate that such a hazard has affected them or poses a credible risk to them. The diversity of harm claimed across the case studies show that this causal link draws on a particularly wide range of evidence and disciplines. To date, claimants have mainly focused on demonstrating the impacts of a particular hazard on their specific circumstances. However, the emerging field of impact attribution, which estimates the broader social and economic costs attributable to climate change, may help future claimants in strengthening this link.

Claimant arguments

This causal link can involve a diverse range of scientific disciplines. This reflects the diversity of past, current and future damages that can be linked to climate change. Climate-related harm is extraordinarily varied in its nature, affecting agriculture, infrastructure, public health, mental wellbeing and economic stability, among many other areas. This complexity is compounded when considering the different types of 'impact' present in the case studies. Some cases seek compensation for past damage caused by climate change (e.g. *County of Multnomah v. Exxon Mobil Corp.* and *City & County of Honolulu v. Sunoco LP)*, while others claim for adaptation costs amid current or future risks (e.g., *Asmania v. Holcim* and *Lliuya v. RWE*). In practice, many cases involve elements of both: in *Lliuya*, for instance, the claimed harm concerns a present and ongoing risk of a future glacial flood, while *Asmania* combines claims for past damage from sea level rise with forward-looking demands. This differentiation matters because it affects the types of evidence required. Claims focused on past damage will draw on evidence assessing the role of climate change in events that have already occurred, whereas claims centred on future risk require projections drawing on fields such as engineering, economics and climate modelling.

Assembling a robust case on impact often requires expertise from a range of disciplines. In the case studies, claimants have used a wide variety of sources to demonstrate the impacts of specific physical hazards. For example, in *Falys v. TotalEnergies*, the claimant presented purchase invoices, selling prices and reports on the average crop yield to establish the damage to his strawberry and potato crops caused by a 2016 storm.[14]

Claimants may argue that a hazard has given rise not only to economic damage, but also to other forms of harm that are broader in nature and less readily quantifiable. In the cases *Falys v. TotalEnergies*; *Asmania et al. v Holcim*; *Ma et al. v. KEPCO et. al.*; and *Leon v. Exxon*, the claimants raised non-material damage, including the impacts of increased workload, stress and eco-anxiety. These claims reflect a growing recognition that harm attributable to climate change extends beyond financial loss. These claims require specific forms of expertise to support them. In the case of *Held v. Montana*, the claimants presented a report by a psychiatrist to assess the impact of climate change on the mental health of children in Montana, including the youth claimants in the case.[15] Although not a polluter pays case, it highlights the breadth of evidence that may be relevant to demonstrate different climate impacts.

Although it has not yet played a central role in polluter pays litigation, the emerging field of impact attribution may expand this breadth of evidence. Impact attribution focuses on calculating and assessing the role of climate change on the social and economic impacts of physical hazards, such as heatwave, flood or storm.

Attribution science explainer: impact attribution

Definition: Impact attribution links climate change to the social and economic impacts of physical hazards and extreme weather events. Impacts can be attributed based on the change in the probability or the intensity of the event linked to climate change. In all cases, while the analysis considers how climate change affects physical hazards, it assumes that the exposure of the people and infrastructure to the hazard, and their underlying vulnerability, remains unchanged. Impact attribution studies can, for example, estimate how much more expensive a storm has become in a world that is +1.3°C above pre-industrial temperatures, or how many more lives have been lost during a heatwave because of human-made climate change. It has led to findings including that US$143 billion per year of the costs of extreme events is attributable to climatic change (Newman and Noy, 2023) and that an individual offshore gas project in Western Australia will lead to an additional 484 heat-related deaths in Europe (Abram et al., 2025).

Importance: Impact attribution is particularly relevant for climate litigation as it can translate how a change in hazard frequency or intensity relates to climate-related harm and damages. This in turn helps to quantify the share of impacts that can be directly attributed to climate change. However, impact attribution is more novel than other types of attribution science and is subject to more scientific debate and uncertainty.

Methodology: To understand how the intensity of a hazard translates into impacts, scientists develop mathematical functions and models linking these two variables. These range from relatively simple statistical relationships, such as exposure–response functions that map temperature to mortality rates to more complex damage and loss models (Noy et al., 2024). These functions or models are based on historical observational data and are used to calculate an event's impacts in factual and counterfactual climate conditions. The attributable impact is defined as the difference between an event's impacts in today's world and in a world without anthropogenic climate change. In many cases, the relationship between the hazard and the impacts is non-linear and a small increase in intensity can result in much greater harm and damages. The functions or models are context specific and, depending on the type of impact, are calibrated at regional, country or subnational levels. For mortality related to heat, for example, exposure–response functions are usually developed at the subnational or city level. This is because very local factors, such as housing insulation, the availability of green spaces and early warning systems affect how vulnerable people are to heat. These functions must also be updated over time as new impact data becomes available to account for potential adaptation.

Challenges: Impact attribution typically links changes in hazards to aggregate impacts at a larger scale. In the context of a litigation case, an impact attribution study may not be able to directly assess harm or damage to an individual claimant. Moreover, the impacts from extreme weather events are not recorded systematically and exhaustively across the globe, leading to data gaps (Vicedo-Cabrera et al., 2021).

[14] See Complaint: https://cdn.climatepolicyradar.org/navigator/AUT/2024/hugues-falys-fian-greenpeace-ligue-des-droits-humains-v-totalenergies-the-farmer-case_134cce0f52cc968b56948aa1df8d21f0.pdf

[15] See Expert Report: https://climateattribution.org/resources/legal-resource-expert-reports-of-lise-van-sustern-m-d-held-v-state-of-montana/

Some types of impacts and extreme weather events are also more reported than others. This is one of the main challenges for conducting impact attribution studies in contexts where data is scarce, such as in low-income countries. Depending on the type of hazard/impact combination, data and models need to be available at very local and granular levels. It can also be difficult to validate whether estimated impacts have actually occurred. For example, it is challenging to validate how many people died from a particular heatwave because heat is rarely listed as the primary cause of death on death certificates (Lo, 2025).

At present, impact attribution is best suited to assessing climate-related costs and harm at aggregate scales, such as the national or regional costs of a class of extreme events, rather than the specific circumstances of an individual claimant. However, advances in methodologies are producing greater granularity. As these methods develop, impact attribution may become a more directly applicable source of evidence for the first causal link in polluter pays claims.

Causal link 2: climate hazard to global warming

In the second causal link, claimants demonstrate that a climate-related physical hazard was caused or intensified by anthropogenic climate change. Physical hazard attribution, the sub-field of attribution science that assesses the influence of human-induced climate change on specific weather events and longer-term trends, provides the primary evidence for this link. Across the case studies, claimants have used attribution evidence to connect a range of hazards to climate change, from specific extreme weather events such as heatwaves and floods to slow-onset changes, such as sea level rise and glacial retreat.

Claimant arguments

In the case studies, claimants use **physical hazard attribution** to demonstrate a clear link between climate change due to greenhouse gas emissions and an event that has affected them. The specific hazards vary across the case studies. For instance, in *Asmania v. Holcim*, the claimants, who live on the Indonesian island of Pari, argue that climate change has caused both global sea level rise, and relative sea level rise on Pari. To do this, they presented a commissioned expert attribution report by the Global Climate Forum. In *County of Multnomah v. Exxon Mobil Corp*, the claim focuses on a specific extreme weather event: the 2021 Pacific Northwest heat dome, an unprecedented and destructive extreme heat event. To support their arguments, the claimants cite an attribution study that concluded: "the occurrence of a heat wave of the intensity experienced in the study area would have been virtually impossible without anthropogenic climate change" (Philip, 2021). Table 2.1 illustrates the different hazards and events present in the case studies.

Table 2.1. Hazards and events in the case studies

Case	Event/hazard
Luciano Lliuya v. RWE AG Peru	Retreat of the Palcaraju glacier in the Cordillera Blanca, Peru; risk of a glacial lake outburst flood (GLOF) from Lake Palcacocha.
Asmania et al. v. Holcim Indonesia	Sea level rise, extreme water level events, coastal flooding and erosion, coral reef and mangrove degradation, groundwater salinisation. Specific flood events in 2019, 2021 and 2022.
Falys v. TotalEnergies Belgium	Storm event (2016); heatwaves and drought (2018, 2020, 2022).
City of Oakland v. BP p.l.c. California, USA	Accelerated sea level rise; coastal flooding during storms; periodic tidal flooding; increased coastal erosion.

Case	Event/hazard
City & County of Honolulu v. Sunoco LP Hawaii, USA	Sea level rise, coastal flooding and erosion; increased frequency and intensity of hurricanes, tropical storms, rain events, heatwaves and drought; ocean warming and acidification.
County of Multnomah v. Exxon Mobil Corp. Oregon, USA	2021 Pacific Northwest heat dome; wildfires and smoke (September 2020); floods and mudslides; 2022 heatwave; severe and prolonged drought.
Native Village of Kivalina v. ExxonMobil Corp. Alaska, USA	Rising temperatures reducing sea ice extent, thickness and duration; increased exposure to waves, storm surges and coastal erosion. Severe winter storms in 2004 and 2005.
Ma et al. v. KEPCO et. al South Korea	Extreme heat and erratic weather; storms, wildfires and floods across different claimants and seasons.
Leon v. Exxon Oregon, USA	2021 Pacific Northwest heat dome (same physical event as *County of Multnomah v. Exxon Mobil Corp.*).
Pakistan Climate Cost Case Pakistan	Catastrophic flooding across Sindh province in 2022.
Casquejo and others v. Shell plc and another (the Odette Case) Philippines	Super Typhoon Odette, which struck the Philippines in December 2021.

Science explainer: physical hazard attribution

Definition: Physical hazard attribution is the body of attribution science that determines the extent to which human-induced climate change has influenced a specific physical climate event or trend. Physical hazards are defined by the IPCC as “climate conditions with the potential to harm natural systems or society” (IPCC, 2021). A distinction can be made between two broad categories of hazard: extreme weather events and slow-onset events. Extreme weather events, such as heatwaves, extreme rainfall, storms and extreme cold, are characterised by their rapid onset, short durations and high intensity. Slow-onset events, on the other hand, unfold over longer timeframes and are characterised by gradual but compounding impact. These events include sea level rise, glacier retreat, ocean acidification and desertification. In these events, attribution science focuses more on quantifying the measurable contribution of anthropogenic emissions to observed trends over time.

Methodology: The scientific field of detection and attribution, introduced in Part 1 of this guide, has studied both long-term climate trends and specific extreme weather events. For slow-onset changes such as sea level rise, glacier retreat and shifts in precipitation patterns, this methodology compares observed long-term trends against what would be expected from natural variability alone, quantifying the contribution of anthropogenic emissions to the observed change over time.

For specific extreme weather events, the primary methodology is probabilistic event attribution. This approach involves comparing two worlds: the factual world in which a climate event occurred and a counterfactual world without anthropogenic climate change. This comparison is carried out using observational data and climate models and can produce findings on a variety of factors. Box 2.1 illustrates what these factors may be, illustrating the many ways in which climate change can alter a hazard. Other specific event attribution approaches have been developed, such as storyline approaches that are complimentary to the probabilistic methods (Shepherd et al., 2018). Rapid attribution methods have also been developed, enabling scientists to assess the role of climate change in the immediate aftermath of an event, with World Weather Attribution being the most prominent body applying this approach (see also Part 1).

Box 2.1. How does climate change alter climate hazards?

Climate change can alter the intensity and magnitude, frequency, duration, timing and spatial extent of a region's climate hazards. These terms are explained below:

Magnitude and intensity: the raw value of a climate hazard, such as increase in temperature or the height of a flood.

Frequency: the number of times that a climate hazard reaches or surpasses a threshold over a given period, such as the number of heavy snowfall events or floods experienced in a year or over a decade.

Duration: the length of time over which hazardous conditions persist beyond a threshold, such as an increase in the number of consecutive months of drought conditions or the number of days that a tropical cyclone affects a location.

Timing: the occurrence of a hazardous event in relation to the course of a day, season, year or other period, such as the time of year when migrating animals expect to find a seasonal food supply.

Spatial extent: the region in which a hazardous condition is expected or occurred, such as an area threatened by tropical cyclones or terrain where permafrost is present.

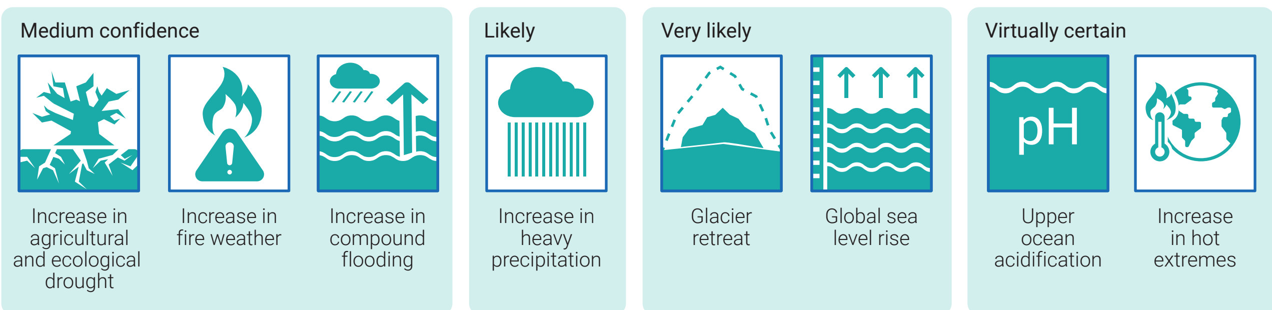
[Adapted from the IPCC's *Climate Change 2021: The Physical Science Basis*, page 1,875, FAQ 12.3, 'How Will Climate Change Affect the Regional Characteristics of a Climate Hazard?']

Challenges: One crucial set of challenges for physical hazard attribution concerns the availability of data and climate model representation. Attribution studies require good observational data to establish what actually occurred, and climate models that can realistically simulate the type of event or trend in question. Where observational records are sparse or climate models cannot adequately capture the relevant physical processes at the necessary scale, conducting robust attribution becomes more difficult. These two constraints often coincide: better data and more reliable models are typically available in wealthier countries (Otto, 2020). A 2024 analysis by Carbon Brief found that out of all the extreme event attribution studies that had been published, the studies predominantly focused on extremes in Europe (22%), Eastern and Southeast Asia (22%) and Northern America (19%). In contrast, relatively few of the studied extremes occurred in Central and Southern Asia (5%), Oceania (1%) and Northern Africa, including most of Sub-Saharan Africa and Western Asia (1%).

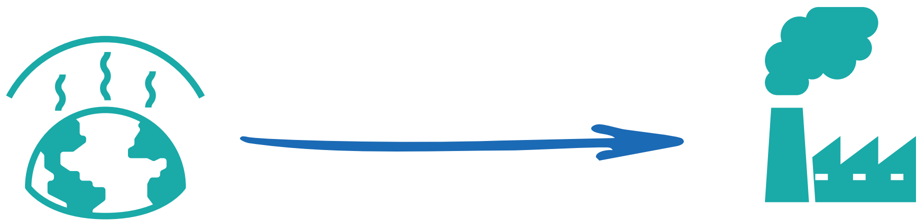
Another challenge is the relative difficulty in attributing different types of hazards to human influence (Figure 2.2). This is due to the varying complexity of modelling different physical processes. Heatwaves are among the easiest physical hazards to model, given that the connection between global warming and localised heat extremes is relatively straightforward and, in most cases, spans large spatial scales that are feasible for climate models to resolve. On the other hand, droughts are more complex because they involve the interplay of many factors, including temperature, precipitation levels and human factors, such as deforestation. Figure 2.2 is a reproduced diagram from the IPCC, displaying the relative confidence about the attribution of physical hazards to human influence.

Figure 2.2. Relative confidence in the attribution of physical hazards to human influence (reproduced from IPPC, 2023)

Attribution of observed physical climate changes to human influence:



Causal link 3: global warming to major emitter



In the third causal link, claimants in polluter pays litigation trace global greenhouse gas emissions back to specific major emitters, drawing on evidence that quantifies the historical emissions attributable to those individual companies. Claimants have also addressed related questions, including when defendants could reasonably have been expected to know their emissions were causing harm, and which approach should be used to quantify a company's emissions. The field of attribution science relevant to this causal link is 'source attribution', which extends attribution studies to consider the role of specific emitters. The science explainer in this section discusses both this area of attribution science and the primary dataset that underpins this research. The link between emissions and global warming is discussed in Box 2.2.

Legal arguments

The third causal link uses source attribution to trace emissions to specific entities and pair this with various legal arguments. Source attribution serves important evidentiary functions. Most fundamentally, it establishes that a given defendant has, in fact, emitted greenhouse gases. Beyond this, it supports two further arguments. Where claims have adopted a proportional responsibility approach[16] (where the defendant must pay for their specific damage caused), a defendant's historical emissions share can inform how damages are apportioned. Both *Lliuya v. RWE* and *Asmania v. Holcim* engaged with this approach, arguing that defendants would be responsible for damage in proportion to their contribution to global industrial CO_2 emissions. In *Lliuya*, this meant seeking compensation proportional to RWE's 0.38% share and in *Asmania*, proportional to Holcim's 0.42% share. Source attribution data also enables claimants to distinguish major industrial emitters (known as 'Carbon Majors') from ordinary actors, grounding the argument that certain large emitters bear a different level of responsibility. The court in *Lliuya* notably addressed this point, highlighting that the defendant's emissions amounted to roughly a tenth of that of the world's largest single emitter, concluding that RWE's emissions were "significant".[17]

In some cases, it may be necessary for claimants to show when a defendant could reasonably have been expected to know that its emissions were causing harm. Different cases have pointed to different thresholds. In the 2025 *Lliuya v. RWE* judgment, the Hamm Higher Regional Court found that a company of RWE's scale should have known that its emissions contributed to global warming since at least the mid-1960s, if not earlier, pointing to the Keeling Curve study of 1958 as evidence of an early study that confirmed the link between greenhouse gas emissions and global warming. In *City and County of Honolulu v. Sunoco LP*, the claimants similarly argue that defendants are responsible for emissions from 1965.[18] This raises further evidentiary demands, where claimants may have to present evidence that shows defendants knew (or ought to have known) that their emissions would cause harm, including early scientific studies and evidence from the defendant's internal communications.

Science explainer: source attribution

Definition: Source attribution describes the process of tracing responsibility for greenhouse gas emissions or climate impacts to specific companies, industries or other entities. This can mean simply identifying which companies produced which emissions. But it can also extend to quantifying the contribution of specific emitters to particular climate events or impacts – for example, estimating how much of the rise in global mean sea levels can be linked to the world's 90 largest carbon producers (Ekwurzel et al., 2017) or attributing specific heatwaves to the emissions of major fossil fuel companies (Quilcaille et al., 2025).

[16] The use of proportional liability also differs by jurisdiction.
[17] See p.47 in Judgment: https://cdn.climatepolicyradar.org/navigator/DEU/2015/luciano-lliuya-v-rwe-ag_e585fec2553b5e2374b8a576e43d07ce.pdf
[18] See p.4 in Complaint: https://cdn.climatepolicyradar.org/navigator/USA/2020/city-county-of-honolulu-v-sunoco-lp_d5cdb9d20bbc4a983bebab49175eea61.pdf

The source attribution field originated with a paper published in 2013, *Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010* (Heede 2013), which calculated the historical emissions attributable to 90 of the world's largest fossil fuel and cement producers. This research led to the Carbon Majors database, an interactive dataset now covering 178 entities.

This area of attribution science is arguably different to other areas of the field because, while it may rely on typical attribution methods, it also relies on normative assumptions and decisions that are required to allocate emissions to specific entities. We explore this further below.

Methodology: There are varying approaches to quantifying a company's emissions, arising in the case studies and beyond. Where companies are subject to self-reporting or state-imposed reporting obligations, allocating emissions is theoretically straightforward. In practice, however, most climate litigation involves historical emissions that predate modern reporting standards, and available emissions data have typically been collected at the country- rather than the company-level. There are also different methods to quantify emissions (Carbon Majors,. n.d.)

One method to quantify emissions is a framework developed under the Greenhouse Gas Protocol, which categorises emissions according to a company's operational relationship to how the emissions are produced. Under this framework, there are three categories of emissions:

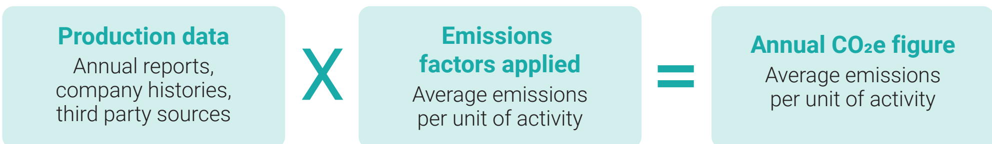
- **Scope 1 emissions:** direct greenhouse gas emissions from owned or controlled sources, such as a factory's emissions
- **Scope 2 emissions:** covers indirect emissions from the generation of purchased electricity consumed by the company
- **Scope 3 emissions:** includes all other indirect emissions, such as those from the supply chain or consumer use of a product (Walker-Crawford et al., 2026a)

This framework has featured prominently in corporate framework litigation, where claimants have argued that companies should be required to reduce emissions across all three scopes. In the context of polluter pays litigation, the question of whether defendants bear responsibility for Scope 3 emissions – those arising from the end use of their products – has been contested (Walker-Crawford et al., 2026b).

The second approach to quantify emissions is production-based accounting, as used in the Carbon Majors database. Rather than categorising emissions by scope, this methodology attributes emissions based on the fossil fuels a company has extracted and brought to market, applying standardised emissions factors to estimate the greenhouse gases released when those fuels are combusted. Emissions factors represent average emissions rates for specific sources and are derived primarily from the IPCC's assessment methodologies. The process for cement producers is similar, though emissions are estimated from gross figures reported to the Cement Sustainability Initiative, rather than production data. The result in each case is an annual emissions figure in CO_2 equivalent (CO_2e) units attributable to each entity.

This avoids the double-counting problem inherent in scope-based accounting, where the same emissions can appear in the inventories of multiple companies across a supply chain. However, it involves its own normative choice: attributing end-use emissions to the producer rather than the consumer.

Figure 2.3. The Carbon Majors methodology for fossil fuels



The Carbon Majors database is the primary source used by claimants in polluter pays litigation to establish a defendant's share of global industrial emissions. Claimants cite the Carbon Majors Report in *Lliuya v. RWE*, *City of Oakland v. BP p.l.c.*, *Asmania et al. v. Holcim*, *County of Multnomah v. Exxon Mobil Corp*, *Falys v. TotalEnergies*, *Ma et al. v. KEPCO et. al.*, *Leon v. Exxon*, the *Pakistan Climate Cost Case* and the *Odette* case. In *Native Village of Kivalina v. ExxonMobil Corp.*, filed before the Carbon Majors research was published, claimants instead relied on the US Energy Information Administration's data and a report by Ceres, an environmental non-governmental organisation (NGO), examining emissions from the 100 largest US electric power producers. However, Kivalina did not present a detailed historic emissions profile for the defendants.[19]

Challenges: A notable feature of the Carbon Majors database is that it remains the "only database to aggregate emissions data at the company level on a global scale" (Carbon Majors, n.d.). While this reflects the significant undertaking the database represents, it also means that claimants are using the same source across the cases. This leaves limited scope for cross-validation of methods. The database also has data limitations. Production records from the 19th and early 20th centuries are often incomplete. Where gaps exist, they are filled through interpolation, meaning that emissions figures for some entities in some periods are estimates rather than direct calculations. This may not significantly affect overall calculations, but it may be relevant where precise historical figures are contested, although it is worth raising that these figures are likely to be a notable underestimate. Finally, source attribution blurs the lines between scientific exercise and normative decision making. The Carbon Majors database can show that a defendant produced a given volume of fossil fuels and that this production is associated with a calculable volume of emissions. However, the question of whether that production gives rise to liability remains a matter for legal argument, making this a challenging category of evidence to communicate to legal audiences.

Box 2.2. Incorporating global warming

In this guide, the last two steps of the causal chain (specific harm to climate hazard; and global warming to major emitter) involve making links to global warming.

While we discuss demonstrating responsibility and the counting of emissions, the processes leading from emissions to global warming are not included as part of our science explainers. Rather than engaging with these processes, such as the greenhouse gas effect, we incorporate them as an implied aspect of the first 'causal link' in the diagram. This is a conscious omission that prioritises brevity and lesser understood areas of the science, but also reflects how claimants and defendants have been engaging with climate science in their arguments.

In brief, the greenhouse effect occurs when certain gases in the Earth's atmosphere trap the heat from the sun, warming the Earth's surface. Human activity, particularly the burning of fossil fuels, has increased the concentration of these gases leading to global warming.

The scientific understanding of the link between anthropogenic emissions and global warming has developed over many decades, from early observations in the 1950s, through successive IPCC Assessment Reports that have expressed this link with increasing confidence. By the time of the Third Assessment Report in 2001, the IPCC concluded that most of the observed warming over the preceding 50 years was likely due to increases in greenhouse gas concentrations. Subsequent reports have strengthened this conclusion. This is reflected in claimant arguments, where there has rarely been a need for citing specialised evidence beyond the IPCC to make the link between emissions and global warming. As discussed in the **first guide in this series**, deference to the IPCC on this issue makes it unlikely that courts will contest the broad evidential basis for climate change and the greenhouse effect.

This position is also supported by findings presented in the **second guide in this series**, which observes that corporate defendants are no longer challenging the link between greenhouse gas emissions and anthropogenic climate change, but are adopting other strategies to counter claims for climate-induced damage, such as challenging scientific causation and expert independence, aspects which affect other aspects of the causal chain. Given that this is not a point of contestation for claimants and defendants, it is reasonable that causal chain representations do not emphasise this relationship.

[19] See Report: https://www.nrdc.org/sites/default/files/benchmark2004.pdf.
See Complaint: https://www.climatecasechart.com/documents/native-village-of-kivalina-v-exxonmobil-corp-complaint_db3f

Part 3. Case studies

In this section we explore some examples of causal chains, as presented by claimants in three different European polluters pays case studies. A brief outline of the arguments in each case is presented, alongside a graphical representation of each causal argument.

Luciano Lliuya v. RWE AG

In this case farmer Luciano Lliuya took German energy giant RWE to court in 2015 over the risk posed by melting glaciers to his home in Peru. Lliuya asked the court to declare RWE responsible to bear a share of the costs of protective measures to protect the claimant's property from a glacial flood, reflecting the company's historical contributions to climate change. Filed in Germany, the case was the first polluter pays action to involve a transboundary climate harm and is regarded as a landmark case for establishing that major emitters can, in principle, be held liable for climate loss and damage. The case was decided in May 2025. While the court affirmed this legal principle, it ultimately dismissed the claim on evidentiary grounds.

To link RWE to the flood risk threatening Lliuya's property, the claimant documented a detailed causal chain using attribution evidence. Firstly, the Carbon Majors Report was presented to link the defendant to climate change (RWE's share was 0.47% of industrial CO_2 emissions when the case was filed; later revised to 0.38% based on updated data). The primary risk to the claimant's property arose from the risk of glacial lake outburst flood (GLOF), a sudden release of water from a lake formed at the bottom of a glacier, which had increased in volume due to glacial retreat. To link climate change to the flood risk, the primary piece of evidence presented was a peer-reviewed publication that evaluated the anthropogenic contribution to both the glacier's retreat and GLOF hazard (Stuart-Smith et al., 2021). The key point of contention – and the evidentiary basis for the case's dismissal – was whether a glacial lake outburst flood posed a significant enough risk to the claimant's property. The court found that the risk was not sufficiently likely to occur, dismissing the case.

The court's judgment contained two distinct elements.[20] On the legal principles, the court found comprehensively in the claimant's favour, confirming across some 60 pages of reasoning that major emitters can, in principle, be held liable under German civil law for climate-related harm, including across borders. The court accepted that RWE's 0.38% share of global emissions was sufficient to establish a relevant causal contribution, rejecting the argument that the emissions were too small to matter. It also found that companies cannot shield themselves behind subsidiaries or regulatory compliance (Walker-Crawford et al., 2025).

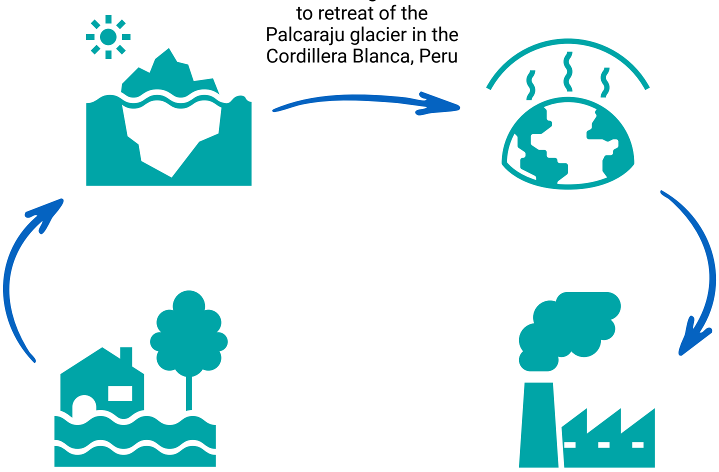
The claim was ultimately dismissed on evidentiary grounds. Under Section 1004(1) of the German Civil Code, the claimant needed to demonstrate that interference with his property was sufficiently imminent. This required showing that a GLOF posed a clear risk to his specific property within a timeframe the court considered relevant, which it set at 30 years. Court-appointed experts assessed this probability at approximately 1%. The court accepted this assessment and rejected the claimant's objections to the methodology used. Notably, the court's own analysis indicated that residents living closer to the river would face a substantially higher risk, underscoring that the dismissal turned on the specific location of the claimant's property, rather than on the viability of the legal theory or the underlying science.[21]

The framing of this question around how risk to property is assessed is significant for future litigation. The German court required a highly localised, site-specific risk assessment focused on whether floodwater would reach the claimant's individual property at a sufficient depth and velocity, rather than a broader assessment of GLOF risk to the region or the wider community. The claimant's own experts had assessed the probability of a GLOF significantly higher, and critiques have been raised about the court-appointed experts' methodology, including their exclusion of rockfall-triggered GLOFs and their reliance on historical data, without fully accounting for the accelerating effects of climate change on GLOF hazard (Grimm and Schirmer, 2025). Because the claim failed at this preliminary evidentiary threshold, the court never reached

[20] See Judgment: https://www.climatecasechart.com/documents/luciano-lliuya-v-rwe-ag-judgment_ceb4
[21] See Judgment: https://www.climatecasechart.com/documents/luciano-lliuya-v-rwe-ag-judgment_ceb4

the question of climate attribution science, meaning that the scientific evidence linking RWE's emissions to glacial retreat was not assessed on its merits.

Figure 3.1. The Lliuya v. RWE causal chain



Asmania et al. v. Holcim

Four inhabitants of the Indonesian island of Pari brought proceedings against the Swiss cement company Holcim for its contribution to climate change and the resulting impacts on their island. This case is a transboundary damages claim seeking compensation for harm arising from sea level rise, specific flooding events and damage to the local ecosystem. The claim is also forward-looking, seeking to impose an emissions reduction obligation on the defendant. An admissibility decision was handed down in favour of the claimants in December 2025, confirming that the legal case was possible. The case is now proceeding to evidentiary hearings.

To link Holcim to the damage caused by sea level rise, among other types of harm, the claimants construct a detailed causal chain using attribution evidence. First, the claimants seek proportional compensation for climate change-related damages on Pari. They argue for proportional compensation in line with Holcim's historical emissions, presenting an expert report by Richard Heede, detailing the carbon history of Holcim Ltd from 1950-2021.[22] To link climate change to physical hazards and then to impacts, the claimants present a report by the Global Climate Forum[23] outlining the "present and future impacts of climate change and sea level rise on the island of Pari". This report uses attribution science, reframes broad conclusions from the IPCC and evaluates satellite and water-level measurements. To provide evidentiary support for the third causal link, the claimants offer witness testimony and observational evidence outlining the impacts of rising sea levels and weather events to their property, health and access to economic opportunities. This evidence, the claimants argue, supports a clear causal narrative between the emissions of Holcim and the impacts on Pari.

In December 2025, the Swiss Cantonal Court of Zug issued a detailed admissibility decision allowing the case to proceed to the merits.[24] The court's reasoning addressed several foundational questions that are likely to be relevant beyond this specific case.

First, the court confirmed that the dispute is a civil law matter, rejecting Holcim's argument that climate protection is exclusively a matter of public law to be addressed through legislative and regulatory mechanisms. Applying multiple methods of legal classification (subordination, function and interest, and modal theory), the court found that the claims are grounded in federal civil law provisions on the protection of personality rights (Article 28, Swiss Civil Code) and tort liability (Article 41, Swiss Code of Obligations), and that the proceedings concern the enforcement of existing legal norms rather than the creation of new climate protection policy.

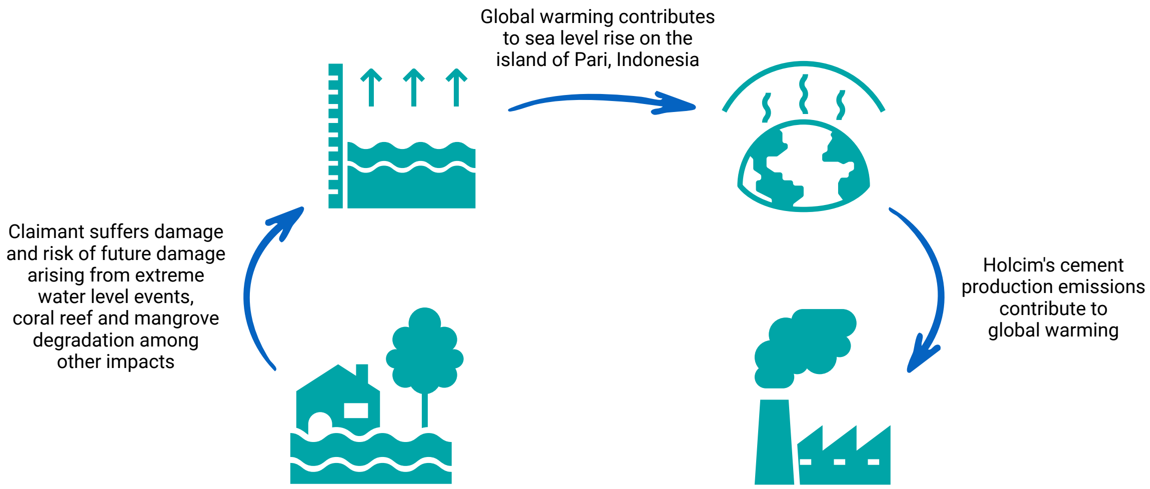
[22] See Expert Report: https://cdn.climatepolicyradar.org/navigator/CHE/2022/asmania-et-al-vs-holcim_c1af1821a35a7a285a22e36e963afa7e.pdf
[23] See Expert Report: https://globalclimateforum.org/wp-content/uploads/2023/01/GCFwp1_2023.pdf
[24] See Decision: https://www.climatecasechart.com/documents/asmania-et-al-vs-holcim-decision_83cf

Second, the court found that the claimants have a sufficient personal interest in bringing the claim, distinguishing this case from the *KlimaSeniorinnen* proceedings before the Swiss Federal Supreme Court, which declined to recognise standing on the basis that the complainants were not seeking to protect individual rights, but rather to review and tighten existing state climate protection measures. The Zug court reasoned that the claimants have already experienced clear, identifiable damage from flooding, loss of livelihood, and threats to their physical and mental wellbeing. The fact that climate change affects many others did not negate the claimants' personal interest in bringing the claim.

Third, the court affirmed that the claim has a practical benefit, rejecting Holcim's argument that its 0.42% share of global emissions is too marginal to make a difference. The court reasoned that if this logic were followed, national climate protection measures would also have to be denied legitimacy, since no single country can stop climate change on its own. The court also rejected the market substitution argument, noting that if the legal case was upheld, other emitters would also have to expect to be held accountable, and that harmful behaviour is not legitimate simply because others behave in the same way.

Finally, the court found the injunction request, which seeks specific annual percentage reductions in the Holcim's group-wide CO_2 emissions across Scope 1, 2, and 3, to be sufficiently specific for enforcement purposes. It noted that Holcim itself uses these terms in its own climate reporting and strategy, and that compliance could be verified under the company's existing reporting frameworks.

Figure 3.2. The Asmania v. Holcim causal chain



Hugues Falys v. TotalEnergies

In this case, Hugues Falys, a Belgian farmer and agricultural engineer, is challenging energy company TotalEnergies in court for damages caused by climate change. This case is the first polluter pays litigation in Belgium and was launched in early 2024 before the Commercial Court of Tournai, supported by three NGOs, FIAN, Greenpeace Belgium and the Belgian Human Rights League. The claimant seeks €135,000 in compensation for material damage to his harvests caused by specific extreme weather events between 2016 and 2022, as well as moral damages for eco-anxiety that he experiences. He also requests injunctive relief from the court, including that TotalEnergies halt investment in new fossil fuel projects, reduce its greenhouse gas emissions by at least 60% by 2030 and adopt a transition plan aligned with the Paris Agreement's temperature goals. Falys has said that he would donate any compensation received to a farming organisation.

To link TotalEnergies to the damage caused to his property, the claimants construct a detailed causal chain using attribution science evidence. To show the first causal link, they cite the Carbon Majors Report, according to which "the TE group alone is responsible for between 0.82 and 0.9% of all historical industrial GHG emissions worldwide".[25] To show the second causal link, the claimants cite the IPCC to make general claims about the impact of climate change on weather events and more regional assessments applicable to Belgium, including a report by Greenpeace.[26] The claimant then uses attribution studies from World

[25] See Complaint: https://www.thefarmercase.be/wp-content/uploads/2025/06/250626-conclusions-synthese-HFvsTE_biffe.pdf
[26] See Report: https://www.greenpeace.org/static/planet4-belgium-stateless/2018/12/cc8aa262-cc8aa262-impacts-des-changements-climat-2.pdf

Weather Attribution among other specific attribution studies (van Oldenborgh et al. 2016) to show the link between climate change and the specific weather events that impacted their property: heatwaves, droughts and flooding. Finally, to support the third causal link, the claimant uses crop data, estimated yields and lost livestock numbers to calculate material damage, as well as alleging non-material damage such as eco-anxiety.

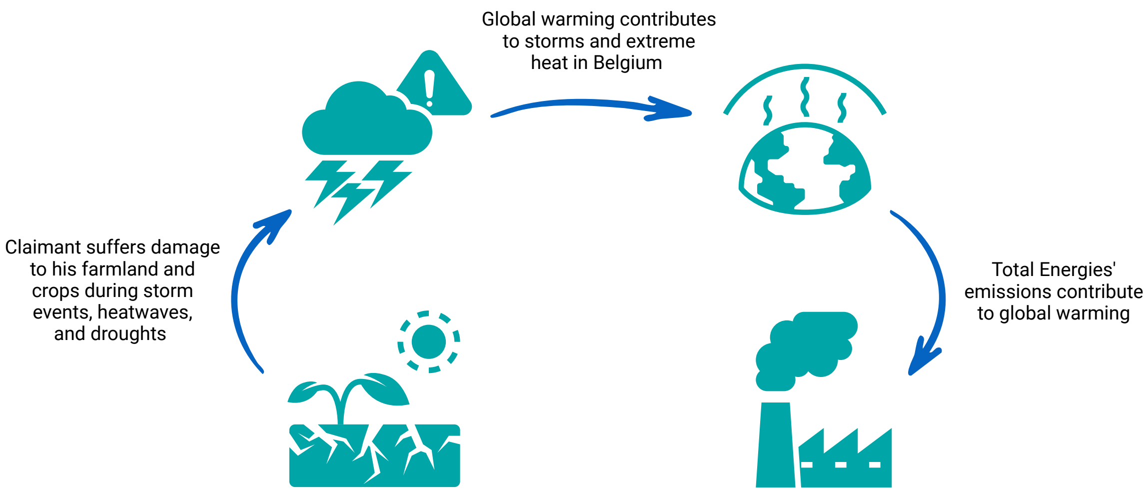
On 18 March 2026, the Commercial Court of Tournai issued a significant admissibility decision, confirming its jurisdiction and declaring the action admissible despite TotalEnergies' objections. The decision addressed several issues of broader relevance to polluter pays litigation.

On issues related to legal jurisdiction, the court confirmed that climate-related claims can be brought in the EU member state where the alleged harm occurred, applying Article 7(2) of the Brussels I bis Regulation. The court found that the forum chosen by the claimant corresponded to the place where the damage materialised, notwithstanding the diffuse and cross-border nature of greenhouse gas emissions. This is notable because TotalEnergies is headquartered in France, not Belgium, and the ruling confirms that victims of climate harm are not required to sue in the defendant's home jurisdiction. The court also recognised the parent company's direct accountability for the group-wide energy strategy, meaning that claims do need to be directed at individual subsidiaries.

On legal standing, the court confirmed that both the individual farmer and the three supporting NGOs have standing to bring the claim. The court recognised that agriculture is directly affected by the climate crisis and that farmers are among its victims.

On the case's legal merits, however, the court stayed proceedings until 9 September 2026, pending the outcome of a parallel case against TotalEnergies before the Paris Judicial Court, in which the company faces claims under the French duty of vigilance law (decision expected on 25 June 2026). Significant questions therefore remain open for the substantive hearing, including the applicable test for causation (the court noted the debate over whether the 'equivalence of conditions' or 'but-for test' should apply, or whether an alternative approach is needed), the admissibility of injunction remedies under Belgian civil liability law, and the limits of judicial intervention in corporate strategy.

Figure 3.3. The Falys causal chain



Conclusion: opportunities and looking forward

Science may provide a starting point for establishing a causal chain in polluter pays claims, but legal arguments and other supporting evidence are also essential. This can be challenging for claimants, with different disciplines needing to converge on a specific question of liability. Claimants must present to legal audiences on complex scientific topics, outlining their conclusions in a legally legible form. As discussed in the first guide in this series, courts tend to favour evidence that reflects scientific consensus. However, polluter pays claims often require evidence at a level of specificity that goes beyond consensus documents such as the IPCC reports. While there is strong scientific consensus that climate change increases the severity of heatwaves globally, for example, the question of precisely how much climate change intensified a particular heatwave in a region, or the extent to which that intensification caused a specific claimant's losses, involves more specialised, sometimes contested methodologies. Claimants must therefore navigate a tension between the authority that comes with well-established consensus science and the precision required to substantiate their specific claims. Evidence that is more specific to the case may carry greater evidentiary relevance, but may also be more open to challenge.

The three strands of attribution science discussed in Part 2 – source attribution, physical hazard attribution and impact attribution – broadly correspond to the three causal links that claimants must establish. However, attribution science alone is rarely sufficient to build a complete causal argument. Claimants also draw on claimant testimony, engineering and economic assessments, archival evidence, and other forms of expertise to connect emitters to specific harm. Legal arguments around proportional responsibility, foreseeability and the scope of liability further shape how courts assess the causal chain. Polluter pays litigation therefore depends on the integration of scientific, legal and other forms of evidence into a coherent narrative, and on the ability of scientists and lawyers to communicate across disciplinary boundaries.

One common issue across the three causal links is uneven data availability, which affects the certainty with which attribution conclusions can be drawn. Attribution studies can be conducted in data-scarce regions, and where observational records are limited or climate models are less well calibrated, the resulting uncertainties are higher. As discussed in Part 2, this unevenness has a significant geographical dimension: data availability and model representation tend to be weakest in the Global South, where communities are often the most vulnerable to climate impacts. The result is that those with the strongest need for robust attribution evidence may face the greatest scientific uncertainties when seeking to produce it. Addressing this will require not only closer engagement with scientists in affected regions, but also broader investment in attribution research focused on the hazards, impacts and data environments most relevant to Global South communities. There is also a question of how legal systems respond to these uncertainties. If evidentiary standards are set without regard to what the science is currently able to deliver in a given context, there is a risk that the most vulnerable populations to climate change may face disproportionate barriers to legal remedies. However, others would argue that consistent evidentiary standards serve important functions regardless of the claimant. How courts and legal systems balance the need for rigorous evidence with the practical limitations of the science remains an open and important question for the future of polluter pays litigation.

Polluter pays litigation is a diverse and rapidly developing area of climate litigation. Recent developments illustrate both its progress and its limitations. The *Lliuya v. RWE* verdict confirmed that major emitters can, in principle, be held liable for climate-related harm under existing private law frameworks, even as the individual claim was dismissed on evidentiary grounds. The *Asmania v. Holcim* and *Falys v. TotalEnergies* admissibility decisions have further affirmed that courts in multiple jurisdictions are willing to hear these claims. At the same time, claimants continue to face significant challenges. Whether existing causation tests are suited to the multi-causal and cumulative nature of climate harm remains an open debate in both the academic literature and the jurisprudence, with some arguing that existing standards are workable when combined with attribution science, and others contending that legal frameworks have not yet adapted to the distinctive features of climate-related harm (see part 1). These questions are likely to be tested further as more cases proceed to evidentiary hearings and decisions on the merits.

Future polluter pays litigation may involve more complex causal chains than those examined in this guide. One potential development is the extension of polluter pays arguments to the financial sector, where claimants would need to establish an additional causal link between a financial institution's lending or investment activities and the emissions they facilitate. While existing cases targeting banks, such as *Notre Affaire à Tous v. BNP Paribas* and *Milieudefensie v. ING Bank*, have been brought as corporate framework claims seeking changes to financing practices, it is conceivable that similar arguments could form the basis of future polluter pays claims. Separately, polluter pays litigation, to date, has focused primarily on carbon dioxide emissions. Short-lived climate pollutants such as methane also contribute to climate harm, and their inclusion in future claims would raise distinct scientific and legal questions, including different atmospheric lifetimes, different measurement challenges and less developed attribution methodologies.

Scientific developments may open new possibilities for claimants in future litigation. One notable example is end-to-end attribution, which combines source, physical hazard and impact attribution into a single analytical framework. Recent studies using this approach have, for example, quantified the heat-related economic losses attributable to emissions from individual emitters (Callahan and Mankin, 2025). At present, these studies operate at broad scales, estimating aggregate impacts across regions or populations rather than damages at the level of an individual claimant. However, the methodology is evolving and may, in future, be able to provide more specific and granular evidence relevant to polluter pays claims.

Given the highly interdisciplinary nature of polluter pays litigation, academic attention must remain on how issues raised in the cases reflect wider trends across disciplines and debates. The challenges explored at the interface of climate science and law reflect wider tensions between the two disciplines. Causal chains are not exclusively applicable to polluter pays litigation, and causal arguments appear in forward-looking framework litigation, project specific cases and cases against governments. Previous studies have recommended that the scientific community should be informed of the needs of litigators to support robust legal decision making, and this is likely to remain the case (Stuart-Smith et al., 2021). However, more communication between scientists and the legal community is essential in both directions, whether through collaborative research, explainers, glossaries and guides for non-specialist audiences.[27]

Polluter pays litigation requires claimants to navigate complex scientific and legal terrain to construct causal chains linking major emitters to specific climate harm. As this guide has shown, recent legal developments have confirmed the viability of these claims in multiple jurisdictions, while also highlighting the evidentiary demands they entail. The scientific foundations for these claims continue to strengthen as attribution science methodologies develop further reach and precision. At the same time, courts, legislators and the scientific community are each grappling with how best to accommodate the distinctive challenges that climate change-related harm presents. How these different fields continue to inform and respond to one another will shape not only the future of polluter pays litigation, but also the broader question of how societies assign responsibility for the consequences of climate change.

[27] See https://cornerstonebarristers.com/the-cornerstone-climate-guide-key-concepts-and-definitions/
https://www.ucs.org/resources/climate-science-legal-contexts?utm_source=linkedin&utm_medium=social&utm_campaign=li

Appendix

Case studies in this guide and their legal bases

Case	Legal basis
Luciano Lliuya v. RWE AG	German law nuisance claim Section 1004 of the German Civil Code: provision for protection against property interference. This provision allows property owners to demand that interference with their property to be removed.
Asmania et al. v Holcim	Swiss law personality rights claim Article 28 of the Civil Code: protection of personality rights claim. Personality rights include physical areas of protection (right to life, personal freedom), psychological (right to family and emotional life), and social (right to name, image and privacy). Right to Financial Compensation under Article 41 of the Swiss Code of Obligations.
Hugues Falys, FIAN, Greenpeace, Ligue des droits humains v. TotalEnergies	Belgian civil liability claim Articles 1382 and 1383 of the former French Civil Code, which oblige natural or legal persons, including companies, who have committed a fault to repair the damage to which they have contributed. There is a duty to repair any harm caused by an individual or entity. This legal basis was also used in the *VZW Klimaatzaak v. Kingdom of Belgium & Others* case.
City of Oakland v. BP p.l.c.	Public nuisance claim Seeking abatement pursuant to California public nuisance law, including Section 731 of the California Code of Civil Procedure, and Civil Code Sections 3479, 3480, 3491 and 3494. [See Complaint p32]
City & County of Honolulu v. Sunoco LP	Five tort-based causes of action Public nuisance, private nuisance, strict liability failure to warn, negligent failure to warn and trespass.
County of Multnomah v. Exxon Mobil Corp.	Four tort-based causes of action Public nuisance, negligence, fraud and deceit, trespass.
Native Village of Kivalina v. ExxonMobil Corp.	Public nuisance claim Broadly similar to the City of Oakland v. BP p.l.c. case.
Ma et al. v. KEPCO et. al	Korean tort liability claim Article 750 of the Civil Act of South Korea.
Leon v. Exxon	Three tort-based causes of action Wrongful death and survival, Washington Product Liability Act and public nuisance.
Pakistan Climate Cost Case	German law tort damages claim Section 823 of the German Civil Code governing liability for damages caused by unlawful acts. Claimants also argue for reasonable compensation under Section 906(2) of the German Civil Code.
Casquejo and others v. Shell plc and another (the Odette Case)	Four causes of action Damages claim under Articles 19, 20 and 21 of the Philippines Civil Code; violation of constitutional rights including the right to a balanced and healthy environment; negligence quasi-delict; and environmental tort claim under Articles 2176 and 2177 of the Philippines Civil Code. Unjust enrichment claim in the alternative.

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