

Climate Change and Causation

Joining Law and Climate Science on the basis of Formal Logic

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Abstract

A strict application of legal tests to find *the cause* of an event has always been a challenge for a coherent causal analysis. This is again the case for making causal statements in the climate change context, although we are witnessing unprecedented impacts of a changing climate at a global scale. While probabilistic event attribution provides information linking greenhouse gas emission levels to observable characteristics of extreme weather and climate related events, the conventional understanding of causation in law provides a very limited response to this scientific

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knowledge. We offer a new matrix for developing causal explanations based on formal logic, for a coherent analysis that is compatible with climate science and law. This matrix causally explains the relation between emissions, the increase in global mean surface temperature, the *general increase* in frequency and severity of climate related events and, most significantly, between emissions and *individual* climate related events.

Keywords: Causation, climate change, climate litigation, probabilistic event attribution, factual causation, legal causation

Introduction

A strict application of legal tests to find *the cause* of an event, combined with a traditional emphasis on finding the *necessary cause* in a counterfactual inquiry and a judicial demand of certainty, sets a high threshold for making causal statements. Often, this threshold of the ‘but for’ test has been found to be over-exclusionary.¹ In the context of climate change, the emerging field of probabilistic event attribution provides significant information to explain past events and to forecast future events related to anthropogenic climate change.² This field of climate science focuses on making robust statements about the role of climate change, quantifying changes in the likelihood of extreme weather events and attributing these to greenhouse gas (GHG) emissions or even certain emitters. For example, one study looking at the Argentina 2013-2014 heatwave

¹ *Fairchild v Glenhaven Funeral Services* [2002] HL 22 [40], Lord Nicholls of Birkenhead stated ‘On occasions the threshold ‘but for’ test of causal connection may be over-exclusionary. Where justice so requires, the threshold itself may be lowered. In this way the scope of a defendant’s liability may be extended.’; see also *March v Stramare (E & MH) Pty Ltd* [1991] HCA 12 [6] where Judge Dean argued that there are ‘convincing reasons precluding its adoption as a comprehensive definitive test of causation in the law of negligence’ [29]. More examples are discussed under 1.1.

² We understand climate change as defined in Article 1(2) of the Framework Convention on Climate Change (UNFCCC): ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.’ The Intergovernmental Panel on Climate Change (IPCC) (the United Nations body for assessing the science related to climate change) refers in a broader sense to climate change as ‘a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.’, IPCC 2018: Annex I: Glossary, in Valerie Masson-Delmotte and others (eds), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C*, 541, 544.

found that this event was made five times more likely due to total anthropogenic emissions and attributed 37 per cent of that probabilistic increase to GHG emissions of the European Union.³

Given that climate scientists are now able to make robust statements quantifying the likelihood of extreme weather events in changing climate conditions, does this allow us to make causal inferences, ultimately ascertaining responsibility in law? We argue that the traditional ‘but for’ or ‘conditio sine qua non’ inquiries used to establish causal relations are inadequate to develop legally meaningful causal explanations in the climate change context. However, a coherent approach to causal analysis is possible within a matrix we introduce. While not attempting to offer a full philosophically rooted, universal model of a theory on causality,⁴ we expose some criteria that the law uses to test causation in the hope to subject these to a much needed discussion of climate change and causation which will affect international law, domestic law, and climate science.

Our matrix is based on the observation that in different categories of cases outside climate change, courts occasionally soften the legal concept of causation to recognise fairness

³ Friederike EL Otto and others, ‘Assigning historic responsibility for extreme weather events’ (2017) 7 *Nature Climate Change* 757.

⁴ Michael Strevens, *Depth: an Account of Scientific Explanation* (Harvard 2008) 6; Wesley C Salmon, ‘Statistical explanation’ in Robert G Colodny, *The nature and function of scientific theories* (Pittsburgh 1970) 173; Patrick Suppes, *A Probabilistic Theory of Causality* (North Holland Publishing 1970) 12; Michael S Moore, *Causation and Responsibility. An Essay in Law, Morals and Metaphysics* (OUP 2009) 3. We will not focus on the Bayesian interpretation of probability, for an introduction into the Bayesian theorem see Judea Pearl, *Causality* (2nd edn CUP 2009) 2; an excellent discussion of the use of the Bayesian theorem and probabilities in jurisprudence is offered by Adam Perry, ‘Strained Interpretation’ (2019) 39 *OJLS* 316, 320.

considerations when differentiating mere co-relation from cause and effect. These normative judgments govern the measure of damages recoverable in tort law and in contract law.⁵

However, this article does not focus on the normative dimension of legal causation, where the outcome of cases is adjusted if the mechanistic application of the ‘but for’ test yields unfair results. These cases are only used as examples to demonstrate that a strict causal tests is not consistently upheld, that instead courts are prepared to comply with demands of fairness and justice. Accordingly, these exceptional cases are discussed with a view to tracing three major challenges that this approach entails for making coherent causal inferences in the climate change context. As a special case in point for climate litigation, the decision of the Essen Court of First

⁵ Ernest J Weinrib, ‘Causal Uncertainty’ (2016) 36 OJLS 135, 140, draws the attention to conceptual operations in handling causal uncertainty in accordance with corrective justice; Emmanuel Voyiakis, ‘Causation and Opportunity in Tort’ (2018) 38 OJLS 26, 28 explores and extends Hart’s and Scanlon’s insights about the justificatory significance of alternative options; for the differentiation between statistic and causal inferences see Richard W Wright, ‘Causation, Responsibility, Risk, Probability, Naked Statistics, and Proof: Pruning the Bramble Bush by Clarifying the Concepts’ (1988) 73 Iowa Law Review 1001; Patrick Shaunessy, ‘A matter of choice: rethinking legal formalism’s account of private law rights’ (2017) 37 OJLS 163; further on the explanatory power of economic analysis William Landes and Eric Posner, *The Economic Structure of Tort Law* (Harvard 1987) 23; Guido Calabresi, ‘Concerning Cause and the Law of Torts: An Essay for Harry Kalven Jr.’ (1975) 43 University of Chicago Law Review 69; Richard Epstein, ‘Causation and Corrective Justice: A Reply to Two Critics’ (1970) 8 Journal of Legal Studies 477; Joseph Gardner, ‘What is tort law for? Part 1: the place of corrective justice.’ (2011) 30 Law & Phil 1; Gregory Mitchell and Philip Tetlock, ‘An empirical inquiry into the relation of corrective justice to distributive justice’ (2006) 3 Journal of Empirical Legal Studies 421.

Instance (Landgericht Essen) in *Lluyia v RWE* is used to demonstrate that a mechanistic application of causal tests will remain insufficient.⁶

For the analytical part of this paper, we then concentrate on developing a novel matrix for causal explanations in the climate change context. The focus in that part rests on the logical fundamentals of legal causation, represented by the existing elements of necessity and sufficiency and, as will be explained and discussed in detail, a new element: sustenance. Sustenance is defined as the capacity of a factor to protect or maintain an effect despite certain structural changes in the model.⁷ With this matrix, the article provides some groundwork that can be used in future judicial reasoning.⁸ However, its potential use goes beyond litigation, as certainty on the threshold requirements of legally meaningful causal connections is an important prerequisite for identifying and presenting relevant scientific evidence and using this evidence

⁶ *Lluyia v RWE AG*, 2 O 285/15, 15 December 2016.

⁷ Pearl (n 4) 309, 316, 317; the element of sustenance, including the mathematical formula that expresses it and underlies the analysis, will be discussed in detail in 3.3.

⁸ Especially if courts establish themselves as ‘cooperative courts’, where ‘specific judgments will make novel and eminently compelling statements that resonate in courts in other jurisdictions’, Eyal Benvenisti, ‘Reclaiming Democracy: The strategic Uses of Foreign and International Law by National Courts’ (2008) 102 AJIL 241, 251; a good example of this mechanism is the order of the Australian Land and Environment Court with references to the *Urgenda* decision of The Hague Court of Appeal, *Gloucester Resources Limited v Minister for Planning* [2019] NSWLEC 7; for the Dutch Judgment see *The State of the Netherlands v Urgenda Foundation* 200.178.245/01 (9 October 2018) ECLI:NL:GHDHA:2018:2610 (unofficial English translation); for a discussion see Petra Minnerop, ‘Integrating the “duty of care” under the European Convention on Human Rights and the science and law of climate change: the decision of The Hague Court of Appeal in the *Urgenda* case’ (2019) 37 JERL 149, 174.

not only in courts but also for advancing international and domestic law which is designed to managing climate change.⁹

The main argument we develop is as follows. There is sufficient robust evidence to establish a strong causal connection between historic and future anthropogenic GHG emissions, an increase in the global mean surface temperature and the severity and frequency of certain individual severe weather and climate related events. To capture this evidence, we introduce the term *distinctive causal field*. This term thus denotes a strong causal connection between anthropogenic emissions and an increase in the likelihood and intensity of classes¹⁰ (or types) of extreme events.

Probabilistic event attribution is used to present the evidence for specific extreme events that can be attributed to certain emitters. Based on formal logic, we open the legal concept to scientific findings where a concrete climate impact can be attributed to a specific emitter.¹¹ This

⁹ 1/CP.21 UN FCCC/CP/2015/10/Add. 1, Paris Agreement, Article 2(2).

¹⁰ An example of a class of events is a heat wave at least as hot, or hotter, than the one observed in 2014 defined over the whole country of Argentina; a class of events is thus not a singular event but all the events that lead to similar or worse impacts in a certain geographical area or sector.

¹¹ *Formal logic* is understood here in a mathematical sense, where mathematical techniques and laws (such as the transitivity theory) are used to develop a valid legal argument, see for a definition of logic, Elliott Mendelson, *Introduction to Mathematical Logic* (6th edn Taylor and Francis 2015) xv-xix; also Patrick Suppes, *Introduction to Logic* (7th reprint Princeton 1964) xviii and 253, semantics or logical syntax are terms used by philosophers to denote a structured and formalised mathematical theory (metamathematics). The use of formal logic is based on the understanding that the concept of causation in law is indeterminate and this cannot be resolved by legal interpretation alone, see Judea Pearl, 'Causes of Effects and Effects of Causes' (2015) 44 Sociological Methods and Research, 149, 152; David W Robertson, 'The Common Sense of Cause in Fact' (1997) 75 Tex Law Review 1765,

is achieved by introducing the property of *sustenance* with which Pearl has revolutionised our understanding of causation across scientific and socio-legal research.¹² Sustenance is used where the logical elaborations of necessity and sufficiency alone are inadequate to fully capture cause-quality in law. It is a key notion to make causal inferences within our matrix. In the context of climate change, and potentially beyond,¹³ this additional property accounts for components of a set of conditions which can be concurrent causes.

The argument is developed in three parts, followed by a conclusion.

Beginning with an explanation of our use of the terms ‘cause’ and ‘concurrent cause’ in Part 1, we briefly present some specific categories of cases where the traditional tests for causation have failed and prompted normative adjustments. We introduce the case *Lluyia v RWE* as a specific case in point to demonstrate three main constraints that the current causal inquiry entails in climate litigation.

Part 2 explains the recent developments and the methods in the field of probabilistic event attribution. This part explains how scientists establish specific evidence that relates the fraction

sometimes further criteria must be added to resolve legal indeterminacy, see Thomas Endicott, ‘Interpretation and Indeterminacy’ Oxford Legal Studies Research Paper No. 96/2013; the complexity of a societal problem can be addressed through adding further connecting elements within a given system, Niklas Luhman, *Die Gesellschaft der Gesellschaft* (Suhrkamp 1998) vol 1, 137 and vol 2, 996.

¹² Pearl (n 4) 316, 317.

¹³ The claim that the legal argument is well reasoned can be limited to a particular legal order or a legal concept constituting the referential framework, however, a more general claim that the legal argument is reasonable beyond this partial framework is not excluded, Robert Alexy, *Theorie der juristischen Argumentation* (Suhrkamp 1986) 351.

of the attributable increase in the occurrence frequency and intensity of individual extreme weather and climate related (slow onset) events to certain emitters.¹⁴

Part 3 joins law and climate science and introduces a thorough discussion of the criteria of necessity, sufficiency and sustenance, including previous attempts to systemically capture concurrent causes in law. We then introduce our proposal of a new matrix for causal explanations in the climate change context. This rests on three pillars, each of them addressing one of the main constraints of the current causal tests. The new matrix thus remains firmly based on the existing counterfactual inquiry but uses an extended logical basis. This allows us to reconcile probabilistic attribution and the various confidence levels which attach to the evidence, for causes that are at least concurrent causes, in a coherent concept of causation in law.¹⁵

1. The Current Legal Framework for Causal Analysis

Despite the fact that differences in the law apply across jurisdictions, the core idea of any causal explanation in law is that mere co-relations between factors can be distinguished from

¹⁴ Slow onset events include the temperature increase, sea level rise, desertification, glacial retreat and related impacts, ocean acidification, land and forest degradation, salinization and loss of biodiversity.

¹⁵ This contributes to the role of law in addressing climate change. The UN Special Rapporteur on extreme poverty and human rights identified climate change as a threat to the rule of law and democracy, A/HRC/41/39 (25 June 2019) para 65; Elisabeth Fisher and Eloise Scotford, 'Climate Change Adjudication: The Need to Foster legal Capacity: An Editorial Comment (2016) 18 JEL 3-4.

mechanisms that cause one factor to produce another.¹⁶ We understand the term ‘cause’ as such factor that can produce an event, without pre-selecting a deterministic or probabilistic relation between the factor and the event that follows.¹⁷ Conversely, the term is used in a wider sense to explain that an event has been produced and a factor will qualify as ‘cause’ of this event if it has at least increased the *probability* of the event’s occurrence in a statistically significant way.¹⁸ On that basis, a ‘concurrent cause’ is defined as ‘an act or event or a state of nature which initiates or permits,... in conjunction with other causes a sequence of events resulting in an effect’.¹⁹ This captures factors that form part of a set of conditions and multi-stage scenarios where a chain of factors lead to an event.

¹⁶ Strevens (n 4) 7. Causal explanations thus differ from statistical explanations, see Salmon (n 4) 173; Suppes (n 4) 12.

¹⁷ Ernest Sosa, ‘Varieties of Causation’ in Ernest Sosa and Michael Tooley (eds), *Causation* (OUP 1993) 234.

¹⁸ Strevens (n 4) 7, 8.

¹⁹ Kenneth J Rothman, ‘Causes’ (1976) 201 *American Journal of Epidemiology* 587, 588. The term concurrent cause is thus used here in line with judgment in the case *Certain Activities carried out by Nicaragua in the Border Area (Costa Rica v. Nicaragua)* General List No. 150 [34], [41], Judgment of 2nd February 2018, where the ICJ for the first time in its history adjudicated compensation for environmental damage.

Across most legal systems,²⁰ and despite many differences across jurisdictions which cannot be discussed in detail here, the core test for causation follows a bifurcated approach.²¹ The first limb is factual causation, where a counterfactual inquiry seeks to identify the factor that was necessary or sufficient for the event. The second limb is finding the legally relevant cause. This involves normative considerations,²² to establish which factor was relevant and which was not, or not to the same extent, and to elude the strictness of a mechanistic application of the test. In the next section, we trace some of the legal developments where the strictness of the causal analysis is coupled with normative correctives, along with the challenges that this presents to a coherent concept of causation. This section demonstrates that our approach is not as radical as it may seem at first instance. It ties in with the observation that pragmatic judicial reasoning surrounds the quest for causal explanations in cases where justice demands a deviation from a strict approach.

²⁰ HLA Hart and Tony Honoré, *Causation in the Law* (2nd edn OUP 1985) 100, 108, 431; Desmond M Clarke, 'Causation and Liability in Tort Law' (2014) 5 *Jurisprudence*, 217. We do not claim to give a complete comparative analysis, the following only demonstrates the approach where a strict causal test is coupled with making normative adjustments. For a recent discussion of different theories pertaining to tort law see John Murphy, 'The heterogeneity of Tort Law' (2019) 29 *OJLS* 455.

²¹ Marta Infantino and Eleni Zervogianni (eds), *Causation in European Tort Law* (CUP 2017) 4, 590; Walter van Gerven, Pieter Larouche and Jeremy Lever, *National, Supranational and International Tort Law* (Oxford: Hart Publishing 2000) 395; Margaret Beazley, 'Damage' in Carolyn Sabbideen and Prue Vines (eds), *Fleming's The Law of Torts* (10th ed, Thomson Reuters 2011) 225, 227.

²² Gerven (n 21) 395.

1.1 Resolving the harshness of ‘but for’ and ‘conditio sine qua non’– examples outside climate change

The ‘but for’ test derived from tort law asks whether the harm would have occurred *but for* the action concerned? The ‘conditio sine qua non’ test which is most familiar to the lawyer from a civil law tradition seeks to define the causal link based on similar counterfactual considerations. Both approaches claim to establish a causal link from a logical-scientific perspective. Using a counterfactual inquiry, the cause-quality of a factor is assessed by a process of elimination of the relevant factor in mind.²³ Consequently, every cause, that cannot be thought to be non-existent without omitting the event in question, is considered to be a factual cause.

Under the limb of legal causation, normative correctives are then applied to identify the factor that not only was necessary for the result as factual cause but is also different from other factors or mere circumstances which are not included in the consideration of the causal chain.²⁴

However, normative correctives are also applied to find the cause in exceptional cases where a strict test of causation would contravene law’s consideration of fairness and justice.²⁵ The following section briefly explores some examples of this approach used in the area of the law of

²³ *ibid* 443.

²⁴ Moore (n 4) 118; Jane Stapleton, ‘Choosing what we mean by “Causation” in the Law’ (2008) 73 *Missouri Law Review* 433, 455; Mill said that ‘..it is very common to single out one only of the antecedents under the denomination of Cause, calling the others merely Conditions’, John S Mill, *A system of Logic, Ratiocinative and Inductive* vol 1 (Gutenberg EBook London 2011) 365.

²⁵ Wex S Malone, ‘Ruminations on Cause-in-Fact’ (1956) 9 *Stan L Rev* 60, 64; Richard W Wright ‘Causation in Tort Law’ (1985) 73 *Calif L Rev* 1735, 1743.

torts, thereby considering aspects of procedural law and substantive law that incorporate normative determinations.

Allocating the burden of proof, setting the threshold of certainty to distribute risks, and shifting the burden of proof, are normative determinations for which the procedural law can account.²⁶ Generally, ‘but for’ causation in the common law of torts entails that a claimant must prove that there was more than a 50 per cent chance that the breach of the duty caused the harm.²⁷ In other words, the action may not be the only factor that causes the type of harm but in the specific situation it must have been *the most likely* one.²⁸ The ‘conditio sine qua non’ test does not use a clear numerical threshold but requires that the court is convinced that a causal link exists.²⁹ Courts may also apply normative correctives which result in shifting the burden of

²⁶ American Law Institute, *Restatement (Third) of Torts* § 26, 441.

²⁷ Kristy Horsey and Erika Rackley, *Tort Law* (5th edn OUP 2017) 249.

²⁸ *Wilsher v Essex Area Health Authority* [1988] AC 1074, 1091; *Bonnington Castings Ltd. v Wardlaw* [1956] AC 613.

²⁹ Grundsatz der freien Beweiswürdigung (principle of independent judicial evaluation of evidence), see Heinz Thomas and Hans Putzo, *Zivilprozeßordnung* (25th edn CH Beck 2003) before § 286 para 2; German Federal Court (BGH) 52 245, 256, *Neue Juristische Wochenschrift* 2000, 953.

proof,³⁰ or allow the claimant to prove only a substantial increase of the risk which eventually led to the harm if a material contribution to the harm itself cannot be proven.³¹

The main category of cases where the outcome of a strict causal analysis is adjusted on the basis of normative considerations consists of concurrent causes in multi-stage scenarios or variations of cumulative causation. In these cases, none of the causes on their own would satisfy the ‘but for’ test or the theory of equivalent causation under the ‘conditio sine qua non’ formula. This could be either in a situation of alternative sufficient causation where other single factors³² or a set of factors could have led to the same event³³ or in a case where all factors must be present for the event to occur.

³⁰ In the Mesothelioma cases, a normatively modified approach to factual causation was established for every single instance of exposure to asbestos in consecutive employments that preceded the harm and increased its risk, even if it was not possible to prove through which specific situation of exposure to asbestos the injury (Mesothelioma) occurred. This results in a reversal of the onus of proof, where the defendant has to rebut the assumption that his action increased the risk, with the increase in risk being treated as the damage.

³¹ *McGhee v National Coal Board* [1973] 1 WLR 1, 4, 8; *Ceri Leigh v London Ambulance Service NHS Trust* [2014] EWHC 286 (QB) [28].

³² *Baker v Willoughby* [1970] AC 467; *McGhee v National Coal Board* [1973] 1 WLR 1; *March v E & M H Stramare Pty Ltd* (1991) 171 CLR 506 (Australia).

³³ So called ‘multiple sufficient causal sets’. The availability of evidence for the causal explanation of the event will decide which factor or set of factors has to be regarded as cause, American Law Institute, *Restatement* (n 26) § 26, 420. The German Civil Code in § 830 sets forth the rule that where several persons participate in a course of conduct which is potentially dangerous to others, even if not as such unlawful, all actors are liable for the full extent of the damage.

The former situation of alternative causation has been clarified in some jurisdictions, so that if ‘multiple acts exist, each of which alone would have been a factual cause ... of the physical harm at the same time, each act is regarded as a factual cause of the harm.’³⁴ Accordingly, uncertainty in relation to the actual tortfeasor shifts the burden of proof onto the defendant.³⁵

In the UK, a very specific exception developed for the legal treatment of concurrent causes in the so-called *Fairchild* line of cases. In these cases, a normatively modified approach was established for every single instance of exposure to asbestos in consecutive employments that preceded the harm and increased its risk, even if it was not possible to prove through which specific situation of exposure to asbestos the injury (mesothelioma) occurred.³⁶ This was followed by legislation to clarify that for this specific category of asbestos exposure cases, all past employers who contributed to the increasing risk are severally and jointly liable, thus each

³⁴ *Restatement* (n 26) § 26, 452.

³⁵ In § 830 of the German Civil Code (BGB), the second sentence of the provision makes a further exception to the general rule of causation, it states that the defendants can be held liable jointly and severally when the identity of the actual tortfeasor or the share of the contribution cannot be determined; for the Netherlands see the case *Christine van Ballegooijen v Bayer Nederland BV (DES daughters)*, where the *Hoge Raad* confirmed the applicability of Article 6:99BW (Burgerlijk Wetboek) in mass tort cases, judgment of 9 October 1992, NJ 1994, 535; for the market share doctrine in the US see *Sindell v Abbott Laboratories* (1980) 607 P 2d 924, Supreme Court of California; the same court limited liability to several only (not jointly) in DES cases, *Brown v Superior Court* (1988) 751 P 2d 470, 486.

³⁶ *Fairchild* (n 4) [40] (Lord Nicholls of Birkenhead). This exception has not been extended so far, *Ministry of Defence v AB and others* [2012] UKSC 9; *Sienkiewicz v Greif (UK) Ltd* [2011] UKSC 10.

of them is liable for the entire harm.³⁷ The *Fairchild* exception has not been extended into other areas so far.³⁸

However, a further group of exceptional cases in the UK concerns the exposure of employees to harmful substances other than asbestos. Here, part of the amount of the harmful substance is considered to be ‘allowed’ and thus, labelled as ‘innocent’, whereas any amount above this threshold falls into the category of being ‘guilty’.³⁹ If then neither the innocent nor the guilty amount alone are deemed as being able to cause the medical condition which the employee suffers, but the amounts together are on the balance of probabilities causal for the harm and thus constitute a set of conditions, it is sufficient that the ‘guilty’ amount made a material contribution to the condition and the claimant is entitled to receive full compensation.⁴⁰

In Canada, legislation has overcome the barrier of a strict causal analysis in multi-stage scenarios involving concurrent causes in tobacco litigation. For litigation relating to the recovery of healthcare costs, causation can be established on an aggregate basis and liability is

³⁷ While *Barker v Corus UK Ltd* [2006] UKHL 20 established only several liability based on the proportion of the attributable risk, the UK Compensation Act 2006, s 3(2)(b) makes provision for joint and several liability.

³⁸ *Jones and others v The Secretary of State for Energy and Climate Change* [2012] EWHC 2936 (QB); *Ministry of Defence v AB and others* [2010] EWCA Civ 1317, appeal dismissed by a slim majority (n 36); see also *Williams v The Bermuda Hospitals Board* [2016] UKPC 4.

³⁹ *Bonnington* (n 28). Where only part of the inhalation of dust was attributable to a breach of a duty, the defendant will be liable on the ground that his breach of duty made a material contribution to the disease.

⁴⁰ *Bailey v Ministry of Defence* [2008] at [46]; *Williams v The Bermuda Hospitals Board* (Bermuda) [2016] PC; *John v Central Manchester and Manchester Children’s University Hospitals NHS Foundation Trust* [2016]; by contrast, only negligible contribution confirmed in *Carder v The University of Exeter* [2016]; a different scenario arises when there are other ‘innocent’ causes and any of these could have led to the harm, as in *Wilsher* (n 28) 1090.

apportioned based on the market share of tobacco companies. Smoking related healthcare costs from tobacco producers can thus be recovered on the basis of specific legislation that sets forth a formula determining the market share and reverses the onus of proof.⁴¹

A slightly different situation of cumulative causation arises when concurrent causes contributed a *certain* proportion to the harm which can be determined, for example when successive employers contributed harmful substances through insufficient working conditions. English and German legal systems will hold each of them liable in proportion to the contribution which can be measured in intensity and duration of exposure; none of the employers is liable for the entire harm.⁴²

Again at a general level, the continental approach to causation is structurally similar to the common law. It introduces normative parameters for causal explanations and supplements these with further theories on the basis of statutory provisions, such as the theory of ‘adequate causation’ and the theory of the protective scope of the statutory norm.⁴³ French law uses the

⁴¹ Tobacco Damages Recovery Act, SBC 1997, c. 41, s. 13; amended by SBC 1998, c. 45, repealed by the Tobacco Damages and Health Care Costs Recovery Act, SBC 2000, c 30; the formula is given in c 30 s 6; for a discussion see Martin Olszynski, Sharon Mascher and Meinhard Doelle, ‘From Smokes to Smokestacks: Lessons from Tobacco for the Future of Climate Change Liability’ (2017) 30 The Georgetown Environmental Law Rev 1, 12.

⁴² *Holtby v Brigham & Cowan (Hull) Ltd* [2000] 3 All ER 421; *McGhee v National Coal Board* [1972] 3 All ER 1008; C Grüneberg, *Palandt, Bürgerliches Gesetzbuch* (77th edn CH Beck 2018) Vorb v § 249 para 34; German Federal Court (BGH) Judgment of 16 June 1959, BGHZ 30, 203; see also Gerven (n 21) 432.

⁴³ Münchner Kommentar zum Bürgerlichen Gesetzbuch, Band 2 Schuldrecht Allgemeiner Teil I (Commentary to the German Civil Code, vol 2 Part I, 8th edn CH Beck 2019) § 249 paras 109-111, Christian von Bar, *The Common European Law of Torts*, vol 2 (OUP 2000) 413.

equivalence theory combined with an explanatory theory for the concrete event.⁴⁴ Under the German Civil Code (*Bürgerliches Gesetzbuch, BGB*), much effort has been dedicated to develop a coherent theory of causation from a bifurcated normative perspective which views causation as a foundation of the existence (*Haftungsbegründend*) and the scope of the liability (*Haftungsausfüllend*).⁴⁵ For causation to be the foundation of liability, the theory of equivalence is the starting point, but this theory is not conclusive of the extent of liability. The theory of adequate causation is used to eliminate *unlikely* factors from the causal chain.⁴⁶ This probability is measured *ex ante*, from the perspective of an objective bystander.⁴⁷ A positive formulation requires that the factor must have increased the probability of any event of such a kind in a not only negligible fashion, for example harm that occurred following medical negligence in the treatment of an injury may still be considered as a consequence of the cause that made the treatment necessary in the first place.⁴⁸

⁴⁴ Gerven (n 21) 419.

⁴⁵ Münchner Commentary (n 43) § 249 paras 104-106; Gerven (n 21) 396.

⁴⁶ Hart and Honoré (n 20) 465.

⁴⁷ Münchner Commentary (n 43) § 249 paras 109ff.

⁴⁸ *Palandt* (n 42) Vorb v § 249 paras 25, 26; The more complicated negative formula eliminates a factor as candidate for an adequate cause for the damage if it could produce the result in question only under particularly unique and quite improbable circumstances to which no attention would be paid if events had followed the normal course. A similar probabilistic element exists in the common law system, where under the test of the 'remoteness of damage' the criteria for 'reasonable foreseeability' assumes the perspective *ex ante*, *Overseas Tankship v Morts Dock Engineering (The Wagon Mound No 1)* [1961] AC 388; *Jolley v Sutton London Borough Council* [2000] 1 WLR 1082.

Using normative correctives and reducing or reversing the burden of proof, are the conventional methods of the law to soften the outcome of causal analysis. This facilitates a re-distribution of risk which often would not be achieved for concurrent causes on the basis of the mechanistic ‘but for’ or the ‘conditio sine qua non’ test.⁴⁹ However, applying these normative considerations in specific cases, all of them outside climate change, does not resolve the systemic difficulties that arise from the strict causal analysis in the context of climate change. Further, it does not account for scientific evidence forecasting the likelihood of future events based on past occurrences of similar events (for example heat waves) and case-specific evidence. This will be demonstrated in the next section.

1.2 Finding the causal link in climate litigation –

Lluyia v RWE as special case in point

Climate change litigation faces many obstacles, often revolving around procedural questions of standing⁵⁰ and jurisdiction,⁵¹ but also as a consequence of applying criteria of established legal concepts – such as causation – to a new challenge.⁵² This is neatly illustrated in the decision of

⁴⁹ Bar (n 43) 416.

⁵⁰ Case T-330/18 *Carvalho and Others*, Order of 8 May 2019, the Court of First Instance reasoned that the applicants were not individually concerned [54].

⁵¹ *American Electrical Power Co (AEP) v Connecticut* 564 US 410; *Native Village of Kivalina v ExxonMobil Corp* 696 F.3d 849, 858 (9th Cir 2012), cert denied, 133 S Ct 2390 (2013); *Comer v Murphy Oil USA Inc* 607 F.3d 1049 (5th Cir 2010); *Verein KlimaSeniorinnen Schweiz v Eidgenössisches Department für Umwelt, Verkehr, Energie und Kommunikation*, judgment of 27 November 2018, A-2992/2017 (in German); Jacqueline Peel, ‘Issues in Climate Change Litigation’ (2011) 1 *Climate Change Law Review* 15, 16

⁵² For a comprehensive analysis of litigation strategies and the role of courts in the climate change context see Geetanjali Ganguly, Joana Setzer and Veerle Heyvaert, ‘If at First You Don’t Succeed: Suing Corporations for

the District Court of Essen in the case *Lluyia v RWE*.⁵³ The claimant, a Peruvian farmer living in the Andes, asserts that his home and livelihood are threatened by the risk of flooding from a glacial lake outburst. The glacial lake Palcacocha is damming glacial meltwater, the water is held by a natural moraine (deposit of irregular mass of debris from a glacier) and controlled by a set of basic pipes to reduce pressure. He claims from the German Energy provider RWE AG a pro rata financial contribution to flood protection measures in proportion to the company's GHG emissions on the basis of Art. 1004 of the German Civil Code (BGB).⁵⁴ The calculation of the compensation is derived from the report on the quantified contribution of 'carbon majors' to cumulative global GHG emissions.⁵⁵ The report states that the company contributed 0.47% to the global total.⁵⁶ The Essen court held that RWE would not qualify as a disturber of the claimant's

Climate Change' (2018) 38 OJLS 841; Jacqueline Peel and Jolene Lin, 'Transnational Climate Litigation: The Contribution of the Global South' (2019) 113 AJIL 679; Sophie Marjanac and Lindene Patton, 'Extreme weather event attribution science and climate change litigation: an essential step in the causal chain?' (2018) 36 JERL 265; Jacqueline Peel, Hari M Osofsky, Anita Foerster, 'Shaping the 'Next Generation' of Climate Change Litigation in Australia' (2017) 41 Melbourne University Law Review 793; Jacqueline Peel and Hari M Osofsky, *Climate Change Litigation* (CUP 2015); Jolene Lin, 'Climate Change and the Courts' (2012) 32 Legal Studies 35, Brian Preston, 'Climate Change in the Court' (2010) 36 Monash University Law Review 15.

⁵³ *Lluyia* (n 6).

⁵⁴ The provision does not require that the property is located in Germany. Further, even a party that acts lawfully may be held liable for damage caused, a legal principle that underlies Art. 1004 BGB but also (as noted by the Hamm court) Article 14(2) of the Federal Emissions Protection Act (BImSchG).

⁵⁵ Richard Heede, 'Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854-2010' (2014) 122 Climatic Change 229, for the full list see Supplementary material at the end of the article.

⁵⁶ Ibid see the Supplementary material, placing RWE as number 28 in the list of 90 carbon majors.

property in the absence of equivalent and adequate causation.⁵⁷ Applying the strict ‘conditio sine qua non’ test of causation, the court was not satisfied that the contribution of RWE could be considered to be significant given the existence of multiple other pollutants, despite acknowledging that the company was a major emitter. However, ‘in the light of the millions and billions of emitters worldwide’ the court was unable to conclude that anthropogenic climate change, and consequently the purported flood risks of the glacial lake, would not occur without RWE’s emissions.

The appeal against this judgment is currently pending in the second instance, the Regional Court in Hamm.⁵⁸ After hearing oral arguments, the Hamm court ordered evidence to be heard.⁵⁹ Under German procedural law, this means that the Hamm court is of the opinion that the case is conclusively (similar to *prima facie* plausibly) argued⁶⁰ and it is now a matter of providing scientific evidence to answer the specific questions asked by the court.

In contrast to the Essen court, the Australian court in *Gray v Minister for Planning* reasoned that merely because the *concrete* contribution of certain emissions could not be accurately measured, this would not suggest that a causal link between the burning of coal and the impact

⁵⁷ In German civil law, equivalent causation is the first step of the test, and the theory of adequate causation functions as a normative corrective.

⁵⁸ Case *Lliuya v RWE* Az 5 U 15/17 OLG Hamm.

⁵⁹ U 15/17 OLG Hamm, order of the Regional Court of Hamm, 1 February 2018.

⁶⁰ The court will only hear evidence if the legal argument is conclusive (*Schlüssigkeitsprüfung*) so that if the facts can be proven, the legal requirements of the statutory provision are fulfilled. The court stated in the order for hearing evidence that concerns regarding the admissibility and conclusiveness of the claim are not justified on the basis of the current factual and legal situation.

on the global climate was insufficient.⁶¹ The issue in question in that case, however, was whether a sufficiently proximate link between mining and GHG emissions, including their impact on climate change, could be established as part of an environmental impact assessment.⁶² Such a situation is different from the attribution of a concrete climate change impact to not only the amount of global GHG emissions worldwide, but to a specific emitter as in *Lliuya*. It is also different from the circumstances in *Urgenda*, where The Hague District Court and The Hague Court of Appeal both found a causal link between emission intensity and the impacts of climate change,⁶³ or the statement of the Supreme Court of Colombia when acknowledging that multiple simultaneous causes impact the ecosystem.⁶⁴

These situations are not considering the causal link between an individual climate related event and overall GHG emissions worldwide or even attributing the event to a narrower group of emitters. These decisions do, however, support the finding that there is a causal link between accumulated emissions and increasing climate change impacts generally.

⁶¹ *Gray v Minister for Planning and Others* [2006] NSWLEC 720 (Pain J) [98].

⁶² *Ibid* [100].

⁶³ *Urgenda Foundation v The State of the Netherlands* C/09/456689/HA ZA 13-1396 (24 June 2015) ECLI:NL:RBDHA:2015:7196 (unofficial English translation, only the Dutch text of the ruling is authoritative, ECLI:NL:RBDHA:2015:7145) [4.90]; *The State of the Netherlands v Urgenda Foundation* 200.178.245/01 (9 October 2018) ECLI:NL:GHDHA:2018:2610 (unofficial English translation) [64].

⁶⁴ STC4360-2018, 5 April 2018, *Tutela of Andrea Lozana Barragán et al v The President of the Republic of Colombia and Ministries*. A tutela is a legal remedy to protect fundamental rights. The Supreme Court of Justice ordered the protection of the Colombian Amazon from deforestation through an intergenerational pact for the life.

On that basis, the most far-reaching decision in finding a causal link between climate related events and a concrete source of emissions is *Gloucester Resources Limited v Minister for Planning*, where NSWLEC posited that there is a causal link between the planned project (a new coal mining plant) and the project's cumulative GHG emissions and further climate change and its related consequences.⁶⁵ Interestingly, the court reasoned that it is sufficient that the project's emissions would 'likely contribute to the future changes to the climate system and impacts of climate change; and that the project was 'likely to have indirect impacts on the environment, including the climate system'.⁶⁶ Thus, the NSWLEC acknowledged a causal link in the light of the scientific treatment of corresponding uncertainty levels.

This decision is one in an increasing number of climate litigation cases, demonstrating that systemic issues remain in the application of the 'but for' test of causation, when attributing specific climate related events to global GHG emissions or concrete emitters. The following section summarises, on the basis of the case law discussed in the two previous sections, three systemic constraints of our conventional approach to test causation in the climate change context.

1.3 Three Constraints for causal explanations

The existing framework of causal analysis confronts a coherent approach to causal explanations in the context of climate change with three major constraints.

The first constraint is that the current approach couples a strict causal test with normative adjustments for some specific ex-post causal explanations, however, no such treatment has been devised at a comprehensive level. The harshness of the causal test is only alleviated through

⁶⁵ *Gloucester* (n 8) (Preston CJ) [525].

⁶⁶ *Ibid.*

case-specific normative correctives – none of these have been sufficiently elaborated in the climate change context so far,⁶⁷ leaving the strict ‘but for’ analysis as the default position in law.

The second constraint is that the existing framework lacks the means of reflecting scientific evidence that makes projections about changes in *probability* of any future weather or climate related events with various degrees of confidence levels. This ignores the potential of climate science because it undermines the underlying question of causal analysis: How could the attributed (weather or climate) event be prevented in the future? Portraying factual causation through a counterfactual enquiry necessarily compares the existing world with a counterfactual world, where higher uncertainty *is* associated with the latter. The ‘but for’ test claims to be based on mathematical operations yet in reality is inherently limited by what we think would have happened in the absence of the event. This not only presumes we can single out one specific factor but also that the event in its concrete form occurred because of this factor. It pretends certainty where always only degrees of likelihood can exist.⁶⁸

⁶⁷ For the underlying role of these principles for justice considerations, John Rawls, *Justice as Fairness, a restatement* (E Kelly, ed. Harvard 2003) 6, 132. This lack of normative correctives is partly due to the fact that climate change involves a convergence of factors which constantly threaten ethical behaviour and defy moral standards. For a discussion of these moral dimensions see Stephen M Gardiner, *A Perfect Moral Storm: The Ethical Tragedy of Climate Change* (OUP 2011) 22, 24; Stephen Gardiner and David A Weisbach, *Debating Climate Ethics* (OUP 2016) 15.

⁶⁸ This is a persistent logical challenge in social sciences, see Max Weber, ‘Critical Studies in the Logic of the Cultural Sciences’ in Edward Shils and Henry Finch (eds), *The Methodology of Social Sciences. Max Weber* (ed reprint, New York 1969) 113, 169-173.

A third and major constraint concerns the role of concurrent causes. The ‘but for’ test neglects a contributing factor as potential cause-candidate if it is not the only necessary or sufficient factor that is responsible for the event. The test does not provide a tool for identifying concurrent causes that are components of a set of factors, where only the set *in its entirety* is sufficient for an increased risk or harmful event, or in a situation where only a succession of events leads to the final result.

The following Part 2 briefly explains the emerging field of probabilistic event attribution, its methods and role in climate science, including the two levels of uncertainty treatment in reporting research results. On that basis, Part 3 ties law and climate science together and proposes a new matrix for causal explanations in the climate change context to address the three constraints.

2. Probabilistic Event Attribution

Causally explaining observed changes in the climate system has been the aim of a field of climate science known as detection and attribution since Hasselmann in 1997 developed methodologies to attribute observed trends in global mean temperature to known natural and anthropogenic drivers. In essence, a climate model is used to simulate global mean temperature with and without anthropogenic GHG emissions finding that without these emissions the observed increase (1°C today⁶⁹) cannot be simulated. While traditional detection and attribution methods yield significant results only when trends are very strong, changes in the probabilities of

⁶⁹ Karsten Haustein and others, ‘A real time-Global Warming Index (2017)’ 7 Nature Scientific Reports (15417) 1, 3.

extreme events are more subtle and could thus not be attributed to global GHG emissions at the time of Hasselmann when climate models were extremely costly to run.

2.1 Developments in a New Field of Climate Science

Today, climate science can determine that the Argentina heatwave in 2013-2014 was made five times more likely due to total anthropogenic emissions and the European Union's emissions account for an increase of 37 per cent in the likelihood of this heat wave occurring.⁷⁰ Rapid analyses are used to produce results immediately after an extreme event has occurred, for example to explain that the 2018 heatwave in Northern Europe was made at least twice to five times more likely to occur in many places because of climate change.⁷¹

With the increased availability of large ensembles of climate models, a different field of detection and attribution has emerged: probabilistic event attribution. While differences in the methodology exist,⁷² the main aim of this science is to answer the question whether and to what extent anthropogenic climate change has altered the likelihood and intensity of an individual extreme weather event to occur. Using climate modelling and statistical modelling, scientists estimate the probability of an event to occur with climate change (P1) and in a counterfactual climate of a world without anthropogenic GHG emissions (P0), thus causally linking the

⁷⁰ Otto (n 3) 757.

⁷¹ Report of the Environmental Change Institute (ECI), School of Geography and Environment, Oxford University, in collaboration with the World Weather Attribution initiative (WWA), available at www.worldweatherattribution.org/attribution-of-the-2018-heat-in-northern-europe, last accessed 4 December 2019.

⁷² Friederike EL Otto and others, 'The attribution question' (2016) 6 *Nature Climate Change* 813, 814; Michael E Mann, Elisabeth A Lloyd and Naomi Oreskes, 'Assessing climate change impacts on extreme weather events: the case for an alternative (Bayesian) approach' (2017) 144, 131.

occurrence probability of severe weather events to external drivers of the climate system.⁷³ On that basis, it is then possible to quantitatively determine even the contribution of individual countries to the changing likelihood of certain extreme weather events as a result of these countries' emissions.⁷⁴

Results of event attribution studies are expressed in risk ratios (RR), describing the change in occurrence frequency of the event caused by anthropogenic climate change.

$$RR=P1/P0$$

Risk ratios are given with confidence intervals representing sampling and methodological uncertainties.⁷⁵ The causal statement thus entails the *identification of a cause*, such as increasing emissions, and represents a *causal quantity* in the shape of the attributable risks.⁷⁶ The design and framing of the attribution study is essential for the interpretation and any further use of results that it delivers.⁷⁷

In particular, the definition of the event that is studied is crucial. For example, defining the heatwave of 2018 as a European temperature average over the whole season June to August will

⁷³ Alexis Hannart and others, 'Causal counterfactual theory for the attribution of weather and climate related event' (2016) *American Meteorological Society* 99, on the use of the Bayes' theorem in science, see Pearl (n49) 14f; Perry (n 4) 320f.

⁷⁴ Otto (n 3) 757, 758.

⁷⁵ Sjoukje Philip and others, 'Attribution analysis of the Ethiopian drought of 2015' (2018) 31 *American Meteorological Society Journal of Climate*, 2465.

⁷⁶ Pearl (n 4) 307.

⁷⁷ Friederike EL Otto and others, 'Attribution of extreme weather events in Africa: A preliminary exploration of the science and policy implications' (2015) 132 *Climatic Change* 531.

result in risk ratios that are much higher compared to a more localised and impact focused definition like maximum heat stress in a city.⁷⁸

A further significant differentiation is made between the types of events that are examined. While the Arctic heatwave in December 2016 was made more than 1000 per cent more likely due to anthropogenic GHG emissions with contributions of the European Union and the United States alone doubling the risk, the rainfall event in the United Kingdom during January 2014 was made 40 per cent more likely by total GHG emissions and only 3 per cent more likely as a result of European Union GHG emissions.⁷⁹ It is also important to highlight that there are extreme events that are made less likely by anthropogenic climate change while for others the risk is unchanged even in a changing climate and, crucially there are events for which current methods and tools are not advanced enough to estimate the change in risk.⁸⁰

While for a number of studied events and variables the climate change signal⁸¹ is relatively linear with global mean temperature increase, this is not always the case. A linear pattern has been found to exist for some regional climate change impacts; for others a quasi-exponential

⁷⁸ See also Luke J Harrington and Friederike EL Otto, ‘Adapting attribution science to the climate extremes of tomorrow’ (2018) 13 *Environ. Res. Lett.* 123006.

⁷⁹ *ibid.*

⁸⁰ Friederike EL Otto and others, ‘Attributing high-impact extreme events across timescales—a case study of four different types of events’ (2018) 149 *Climatic Change* 399, 412.

⁸¹ Climate signals are long-term trends and projections that are linked to climate change. Examples are rising sea levels, increasing extreme precipitation, and warming sea surface temperatures.

increase or a sigmoidal pattern of change exists.⁸² This means that defining a causal relation between GHG emissions and a specific impact depends very strongly on the type of event, the region in the world and temporal and spatial scales of the studied event.

A crucial implication of the development of probabilistic event attribution is that it cannot be applied only after an event has happened and damage occurred. When vulnerabilities and thresholds are known, changing risks can be calculated *ex ante*. In other words, the changing risks can be forecasted. The improvement of the methods allows geographically very specific events to be anticipated and thus, appropriate adaptation measures can be designed.⁸³

2.2 Uncertainty Treatment in Probabilistic Event Attribution

There are two levels where uncertainty treatment plays a role. First, the probability concerning the causal link itself, for example, the anthropogenic GHG forcing increased the likelihood of intense rainfall as measured in the wake of hurricane Harvey in 2017 by a factor of 1.5 to five times.⁸⁴ Second, the confidence level that is attached to this statement; given that climate models are known to be not unbiased in representing hurricanes and only one other independent study

⁸² Luke J Harrington and Friederike EL Otto, ‘Attributable damage liability in a non-linear climate’ (2019) 153 Climatic Change 15.

⁸³ We thank Lindene Patton for stressing this point and the fact that with the ability to forecast, there comes a duty to do so.

⁸⁴ Geert Jan Oldenborgh and others, ‘Attribution of Extreme Rainfall from Hurricane Harvey, August 2017’ (2017) 12 Environmental Research Letters 124009.

with similar findings exists, the confidence in this statement (on Hurricane Harvey) is only medium.⁸⁵

These two levels of uncertainty are independent of whether a projected (ex-ante) or attributed (ex-post) change in the occurrence frequency of an extreme event is large or small. For example, we have *high confidence* that anthropogenic climate change increased the likelihood of extreme precipitation in UK winters by 40% (*likely* range 0-100%) while we have *medium confidence* that the 2015-2017 drought in Cape Town was made 3 times more likely (*likely* range factor 1.4 to 6.4).⁸⁶ The likelihood statements result from statistical analyses of climate data whereas the levels of confidence depend on the climatic variables (temperature, precipitation, pressure etc.) analysed, availability and quality of observed data, strength of theory describing and

⁸⁵ The confidence level reflects the evaluation of the validity of a finding. Generally, evidence is most robust when there are multiple, consistent and independent sources of high-quality evidence. A level of *confidence* is expressed using five qualifiers: very low, low, medium, high, and very high. It synthesises the scientific judgment about the validity of findings as determined through evaluation of evidence and agreement. *Likelihood* provides calibrated language for describing quantified uncertainty. It can be used to express a probabilistic estimate of the occurrence of a single event or of an outcome (e.g. a climate parameter, observed trend, or projected change lying in a given range). Likelihood may be based on statistical or modelling analyses, elicitation of expert views, or other quantitative analyses. The range is as follows: Virtually certain: 99-100% probability, Very likely: 90-100% probability, Likely: 66-100% probability, About as likely as not: 33 to 66% probability, Unlikely: 0-33% probability, Very unlikely: 0-10% probability, Exceptionally unlikely: 0-1% probability, see Michael D Mastrandrea and others, 'Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, at 3, available at https://wg1.ipcc.ch/SR/documents/ar5_uncertainty-guidance-note.pdf, accessed 10 July 2019.

⁸⁶ Friederike EL Otto and others, 'Anthropogenic influence on the drivers of the Western Cape drought 2015–2017' (2018) 13 Environmental Research Letters 1240010.

understanding processes in the climate system, reliability of climate models and the availability of evidence (number of scientific studies as well as number of independent data sources).

How can the increase in risk for which probabilistic event attribution provides the evidence be captured in a standardised causal law? If there are other cumulative factors that contributed to an event and increase the likelihood of the future occurrence of similar events of this kind, but none of the factors passes the traditional threshold set by the ‘but for’ test, is it possible to find a causal explanation? Intuitively, the answer might be positive, however, a more rigorous structural causal law exists and this will be developed in the following part.

3. Three Pillars for Analysis in a New Matrix on Causation

The following part develops a model that addresses the three constraints of the conventional test of causation as discussed in Part 1, making use of probabilistic event attribution as introduced in Part 2. The model is based on Pearl’s explanation of his theory of causation, which is grounded in logical elaborations of the notions of ‘necessary’ and ‘sufficient’ conditions and complemented by ‘sustenance’ as a final element. The model comprises three pillars.

The first pillar is derived from the logical elaborations of the notions of ‘necessary’ and ‘sufficient’ conditions,⁸⁷ which already underlie the legal concept of causation, to identify relevant factors of the causal chain. The strength of the causal connection between these factors is then determined on the basis of the degrees of probability and the confidence levels with

⁸⁷ John L Mackie, *The Cement of the Universe* (OUP 1980) 160; Tony Honoré, ‘Necessary and Sufficient Conditions in Tort Law’ in Tony Honoré, *Responsibility and Fault* (Oxford: Hart Publishing 1999) 94.

which scientific results are reported for each of these factors.⁸⁸ The transitivity theory is applied as a mathematical tool to reflect the logical consequences that the existence and the related strength of a causal link across factors in a multi-stage scenario entails.

The second pillar accounts for climate science, including probabilistic event attribution, to demonstrate that higher amounts of GHG emissions increase the intensity and frequency of climate related events. We introduce the notion of the *distinctive causal field* to capture this strong connection where sufficient event-specific evidence for a plurality of types of events exists.

The third pillar supplements the existing logical fundamentals with the notion of ‘sustenance’ to offer a coherent approach to causal explanations in the climate change context that includes concurrent causes. Probabilistic event attribution is used to explicate the fraction of the attributable risk for a cause that is at least a concurrent cause.

3.1 Necessary and Sufficient Condition

A causal relation between different factors and the degree of confidence that allows concluding from one factor to the existence of another, are regularly established using the criteria of ‘necessity’ and ‘sufficiency’. This reasoning already forms the basis of our legal concept. It is

⁸⁸ Reflecting the idea that an event is caused by all conditions, see John L Mackie, ‘Causes and Conditions’ in *Causation* (n 17) 35; Phyllis Illari and Federica Russo, *Causality* (OUP 2014) 29, Mill (n 24) 367, 373.

concerned with providing proof at every stage of the structural chain of events that the premises imply a certain conclusion.⁸⁹

The following explains causation as a fundamental logical concept, based on the relation between two factors, we call them at this stage N and S. S is a sufficient condition for N if it is true if there is S, we know that there is also N. It is possible to say that S implies N, or whenever there is S, then N is also true. That does not imply that N will *only* be true if there is S: N may also occur in the absence of S, where another factor leads to N. However, S cannot be true without N being present, because N is necessary for S. If we could establish that N will only be true in the case if S is present, we could conclude that N and S are equivalent conditions, where both are sufficient and necessary for each other at the same time. Such an equivalent relation between N and S indicates a very strong causal connection.

The law does not always explicitly discuss necessity and sufficiency and it does not require an equivalent relation to establish the ‘actual cause’. However, the counterfactual ‘but for’ test reflects the strong influence of the necessity element to establish causation in law and consideration to the sufficiency element is given in cases where one main factor lead to the event in question.⁹⁰ Causal claims on the basis of necessary and sufficient conditions can be made in

⁸⁹ Mendelson (n 11) 2; Jan Dul, ‘Necessary Condition Analysis (NCA): Logic and Methodology of “Necessary but Not Sufficient” Causality’ (2016) 16 *Organizational Research Methods* 10, 16; Bear Braumoeller and Gary Goertz, ‘The methodology of necessary conditions’ (2000) 44 *American Journal of Political Science* 844, 846.

⁹⁰ Hart and Honoré (n 20) 109; James J Edelman, ‘Unnecessary causation’ (2015) 89 *Australian Law Journal* 1.

varying shades, depending on the evidence that is available. High levels of confidence and event-specific evidence explicate a strong causal connection between two factors.⁹¹

In returning to our climate change context, we now establish the causal connection on the basis of these two existing logical fundamentals, between the following four factors that climate scientists identify in the multi-stage scenario of anthropogenic climate change: E, T, I_F and I_S. These will be explained in turn. E denotes the quantity of anthropogenic GHG emissions.⁹² T stands for the increase of global mean surface temperature. I_F captures the impacts of a changing climate consisting of a general tendency of increasing *frequency and severity* of some weather events and (climate related) slow onset events. I_S denotes the occurrence of a *concrete* climate change impact, either a severe weather event or a slow onset event.

If there is to be a causal link between a concrete climate impact I_S (for instance severe flooding, a specific heatwave or a hurricane) and E, explaining the relations between E and T, between T and I_F and E and I_F are key steps for the investigation whether I_S could have been anticipated (and thus avoided) and we proceed with this before turning to the direct link between E and I_S, for which attribution science can now also provide the scientific evidence.

Further, a binary relation over a set of factors can generally be qualified as a transitive composition of binary variables, if a chainlike process exists where it is true that ‘X causes Y and

⁹¹ Pearl (n 4) 311.

⁹² E can be defined as the global total or narrower, only including specific emitters. The Carbon Majors Database, ‘CDP Carbon Majors Report’ (2017) 7; Heede (n 55) 234.

Y causes Z regardless of X, it can be concluded that X causes Z'.⁹³ From our understanding of processes in the atmosphere, observational analyses and climate modelling, we know that the occurrence of extraordinary global-scale heat waves, some extreme precipitation events,⁹⁴ droughts and storms in some areas,⁹⁵ cannot be explained without human-induced climate change.⁹⁶ These impacts of climate change I_F , allow us to identify E as cause for I_F where there is a transitive relationship between E, T, and I_F . If the relation between E and T and T and I_F is transitive that means that E is also and *in the same way* related to I_F . To put it differently, this establishes a causal link between GHG emissions and the general increase in frequency and severity in climate change impacts. Transitivity also maintains the strength of the causal relation over the entire set of factors.

Consequently, if we establish a causal relation between an increase of E and the increase in T and the increase in T and increasing frequency and severity of climate change impacts I_F , a causal relation between the increase of E and I_F can also be determined. Depending on the strength of the causal explanation (the level of confidence), this thus allows us to anticipate I_S

⁹³ Ned Hall, 'Causation and the price of transitivity' (2000) 97 Journal of Philosophy, 198, 200; Claudio Pizzi, 'Causality and the Transitivity of Counterfactuals' (1993) 7 O Que nos faz pensar 89, 96; Pearl (n 4) 237; Mendelson (n 11) xx; Suppes (n 4) 215.

⁹⁴ David Keellings and José J Hernández Ayala, 'Extreme Rainfall Associated With Hurricane Maria Over Puerto Rico and Its Connections to Climate Variability and Change' (2019) 36 Geophysical Research Letters, 2964.

⁹⁵ van Oldenborgh (n 84); Harrington and Otto (n 78).

⁹⁶ Martha Vogel and others, 'Concurrent 2018 Hot Extremes Across Northern Hemisphere Due to Human-Induced Climate Change' (2019) 7 Earth's Future 692, 701.

where I_S a narrower defined event comprised within I_F . The following part ties in the scientific evidence between E, T and I_F before then taking a closer look at the relation between E and I_S .

There is sufficient scientific evidence that the present increase in T would not have happened without the increase in E⁹⁷ and more than 97 percent of actively publishing climate scientists agree.⁹⁸ The evidence for the relation between E and T has grown further in the last decade and the confidence level is expressed as *virtually certain* for the human influence as the dominant cause of the observed warming since the mid-20th century.⁹⁹ Cumulative total GHG emissions and the response of T are approximately linearly related.¹⁰⁰ The contribution of E to the increase in T was likely to be in the range of 0.5°C to 1.3°C during the period 1951 to 2010 and is approximately 1°C today.¹⁰¹

This means that between the increase in E and the increasing T exists even an equivalent relation. Both are necessary and sufficient conditions for one another. Increasing E is a necessary condition of the increase of T since 1880. T would not have occurred without E and E is also a

⁹⁷ For the latest figures see ‘The State of Greenhouse Gas in the Atmosphere Based on Global Observations through 2018’ (2019) 15 Bulletin of the World Meteorological Organisation, available at https://library.wmo.int/doc_num.php?explnum_id=10100 last accessed 27 November 2019.

⁹⁸ John Cook and others, ‘Consensus on consensus: a synthesis of consensus estimates on human-caused global warming’ (2016) 11 Environmental Research Letters 048002; further climate.nasa.gov/scientific-consensus, last accessed 4 December 2019.

⁹⁹ IPCC AR5 IPCC International Panel on Climate Change (IPCC), Assessment Report (AR) 5 (2014) 17, available at https://archive.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf accessed 4 December 2019.

¹⁰⁰ Ibid 27.

¹⁰¹ Ibid 17.

sufficient condition for T, because this very concrete temperature increase is a consequence of E. No other factor explains the increase in T.

Scientific evidence further shows that an increase of T implies the occurrence of some more intense and more frequent severe weather events and slow onset events.¹⁰² There has been further strengthening of the evidence for human influence on the frequency and intensity of daily temperature extremes since the mid-20th century, and it is very likely that a human induced increase in average mean temperatures has more than doubled the probability of occurrence of heat waves in some locations.¹⁰³ Changes in many extreme weather and climate events have been observed since about 1950.¹⁰⁴ Slow onset events, such as glacial retreat, can be measured globally and over the last two decades, the Greenland and Antarctic ice sheets have been losing

¹⁰² Changes in many extreme weather and climate events have been observed since about 1950 (see Table SPM.1 for details). It is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale 6. It is likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia; see IPCC AR5 (n 99) page 5. See further Noah Diffenbaugh and others, 'Quantifying the influence of global warming on unprecedented extreme climate events' (2017) Proceedings of the National Academy of Sciences of the United States of America' available at <https://www.pnas.org/content/early/2017/04/18/1618082114.full?sid=9f9ad06e-c8d6-4760-8cac-be3101c05312> last accessed 27 November 2019.

¹⁰³ AR5 (n 99) 19; Geert van Oldenborgh and others, 'Extreme heat in India and anthropogenic climate change' (2018) 18 Natural Hazards and Earth System Sciences 365, Gabriele C Hegerl and others, 'Causes of climate change over the historical record' (2019) 14 Environmental Research Letters 123006.

¹⁰⁴ AR 5 (n 99) 5.

mass, glaciers have continued to shrink and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (high confidence).¹⁰⁵

Up to this point, a strong causal connection can be demonstrated in the form of equivalent causation between E and T and between T and I_F as a *general trend, or expected consequence*, which means that E and I_F are also both, necessary and sufficient conditions in accordance with the transitivity theory. It is correct to say that E implies I_F, E and I_F display an equivalent relation and thus a very strong causal connection.

3.2 Distinctive Causal Field

We introduce the notion *distinctive causal field* to capture this strong connection between E and I_F, where I_F is the general trend of extreme weather and climate related events for which sufficient event-specific evidence for a plurality of similar climate events (for example heat waves) exists. The term *causal field* was first introduced by Anderson and revived by Mackie to explain that all causal claims are made in a certain context, for instance against the background of certain theories or a set of facts which are considered to be common, in order to identify the one factor that was different from the causal field on a particular occasion.¹⁰⁶ The term *distinctive causal field* is used here in a slightly modified version, influenced by the view of Lewis on events that share a common causal history,¹⁰⁷ to describe the general context of expected events within which causation of a single climate related impact is examined.

¹⁰⁵ *ibid* 9.

¹⁰⁶ Mackie (n 87) 35.

¹⁰⁷ David Lewis, *Philosophical Papers*, vol II (OUP 1986) 225, 226.

In addition to using the causal explanation between E, T and I_F to understand the likelihood of I_S as just demonstrated, the causal link between E and I_S can now be established directly using probabilistic event attribution. Thus, changes in E lead directly to impacts as well as via the increased T and the direct link between E and I_S can be observed and measured in accordance with this new scientific evidence. These impacts concern changes in the likelihood and intensity of extreme weather events, such as heat waves in large parts of Europe, Asia and Australia and an increased frequency or intensity of heavy precipitation events in North America and Europe.

Further impacts include slow onset events such as changes in Northern Hemisphere March-April (spring) average snow cover; the reduction of the extent of Arctic July-August-September (summer) average sea ice with average temperature anomalies exceeding widely 2°C and 3°C in places;¹⁰⁸ changes in global mean upper ocean (0–700 m) and global mean sea level rise.¹⁰⁹ The next section accounts for this new scientific evidence in the specific relation between E and I_S . It introduces the notion of sustenance to portray E as ‘concurrent cause’ for I_S in law.

3.3 INUS Condition, NESS Condition, Sustenance

The scientific evidence that establishes an equivalent relation between E and I_F encompasses a strong causal connection for all events that form part of the distinctive causal field. The existence of this distinctive causal field is important for assessing future risks using climate modelling and socioeconomic scenarios¹¹⁰ and for the anticipation of structurally similar events. In addition, as

¹⁰⁸ WMO (n 97) 6.

¹⁰⁹ AR (n 99) 11, 13.

¹¹⁰ Brian O’Neill and others, ‘IPCC reasons for concern regarding climate change risks’ available at <https://media.nature.com/original/nature-assets/nclimate/journal/v7/n1/extref/nclimate3179-s1.pdf> accessed 9 December 2019.

discussed, attribution science identifies E as a cause-candidate in climate modelling for impacts I_S where E is directly linked to I_S . But if E is only part of a set of other factors and not the dominant cause, the law lacks the capacity to respond to these scientific findings. Thus, how can the increase in risk for which probabilistic event attribution provides the evidence, be captured in a standardised causal law, for example to explain causation in our case *Lluyia v RWE*?

In the literature on formal logic, a variety of concepts have been discussed to find a structural causal law that accounts for concurrent causes in multi-stage scenarios. Mackie contended that a cause is at a minimum an ‘Insufficient, but Non-redundant part of an Unnecessary but Sufficient condition’, he calls this an ‘INUS’ condition.¹¹¹ His explanation of ‘cause’ reflects Mill’s idea of defining the cause as ‘the sum of the total of the conditions positive and negative.’¹¹² Mackie’s famous example is that even though an electrical short-circuit causes a fire, it is an insufficient condition on its own, because other conditions such as oxygen are needed in addition, it is non-redundant, because in this concrete instance it produced the spark. A fire can start without electrical short-circuit, it is thus unnecessary, but the *whole set* of conditions on this occasion was sufficient to start the fire.

Assuming that E is insufficient for a concrete I_S , for instance a tropical cyclone, E could still be an insufficient but non-redundant part of an unnecessary condition which is *in its entirety* sufficient on this occasion – cyclones have happened in the absence of E – but for a concrete occurrence of a particular cyclone, E could participate as *part* of the sufficient condition.

¹¹¹ Mackie (n 88) 35; Illari and Russo (n 88) 29.

¹¹² Mill (n 24) 373, 406.

In *Lliuya*, if E would only qualify as part of a set of sufficient conditions, it could entail that E does not pass the test for equivalent or ‘but for’ causation, even if it increases the risk, as was the result of the causal analysis of the Essen court. The influence of the causal risk factor E depends on the prevalence of complementary causes in a set that together represents the sufficient cause.¹¹³ In the current framework of causal analysis, as demonstrated by the Essen court, a strict test does not reflect the contribution of the concurrent cause. Only *ex post*, that is if the risk materialises, could normative parameters (if available and applicable) be used to portray that Is (in the example a glacial lake outburst) was partially caused by E.

Conversely, the INUS condition provides a minimum threshold for causation, which so far has been occupied solely by the requirement of the cause being a necessary or sufficient condition under the ‘but for’ veil which creates the need for further normative corrections as discussed above. Should INUS conditions be included in developing legally meaningful explanations in the context of climate change impacts? An earlier attempt to translate INUS conditions into a legal threshold was undertaken by Wright who diagnosed an urgent need of repair of causation in the law of torts and developed the NESS test. NESS stands for ‘necessary element of a sufficiency set’ and like the INUS test, it subordinates the necessity element under the sufficiency element of causation.¹¹⁴ It offers a better explanation than the ‘but for’ test, however, sharing the same ontological framework as Mackie’s INUS condition means that the NESS test is susceptible to the same criticism.¹¹⁵

¹¹³ Rothman (n 19) 590.

¹¹⁴ Wright (n 3) 1001.

¹¹⁵ But see Richard W Wright, ‘The NESS Account for Natural Causation: A Response to Criticism’ in Benedikt Kahmen and Markus S Stepanians (eds), *Critical Essays on “Causation and Responsibility”* (De Gruyter 2013) 13,

Pearl agrees with the tests set forth by INUS and NESS in so far as he claims that the sufficiency component should be given additional weight in law as it draws the attention to the consequences of one's action.¹¹⁶ At the same time, he confronts Mackie's INUS condition and its NESS relative with strong criticism, which is echoed by others in the discourse on formal logic.¹¹⁷ The major flaw that Pearl identifies is that it is impossible, without further limitations, to extrapolate from INUS and NESS conditions a structural-causal law that distinguishes between formulae that represent stable mechanisms and those that represent circumstantial conditions.¹¹⁸ If such a standard logical syntax cannot be derived from INUS or NESS conditions, he argues that no causal law allowing for causal generalisation can exist.

Kim proposes a way to resolve this shortcoming. He calls for entities that possess both, an element of generality and an element of particularity; the former is necessary for making sense of the relations of necessity and sufficiency, and the latter for making sense of singular causal judgments. In the specific situation of climate change, this could be applied by comparing the *ex ante* causal explanation (forecast or projection) with the *ex post* causal explanation (attribution). Or to be more concrete, to focus on those events where the impacts that occurred, instantiate specific impacts I_S that qualitatively follow our expectation and forecast for I_F .

15; Jonathan Schaffer argues that the NESS test is an excellent test and adds that it is an companion to his contrastive approach, 'Contrastive Causation in the Law' (2010) 16 Legal Theory 259, 287.

¹¹⁶ Pearl (n 4) 308.

¹¹⁷ Kim (n 43) 60, 62.

¹¹⁸ This means that they only exist in the concrete instance, see Mackie's example of the electrical short-circuit; for the criticism Pearl (n 4) 314.

However, that would on the one hand limit the causal analysis to cases where the risk indeed has materialised and harm is suffered (and thus further entertain a bifurcated conceptual approach to causation) and on the other hand also exclude cases where no projections are available for I_S despite the existence of I_F and the fact that the event in question represents a structurally similar instantiation of this distinctive causal field.

Pearl resolves the problem by adding a further component which ties in with the counterfactual approach. Following on from what Hall calls dependence (similar to necessity) and production (close to sufficiency), Pearl introduces the notion of sustenance to supplement the counterfactual analysis.¹¹⁹ Sustenance measures the capacity of the cause to *protect or maintain* the effect under structural changes in the model.¹²⁰ It translates the idea of Lewis on ‘quasi dependence’ into a syntax where contingencies are modified to test the resulting effect and thus, the ability of the factor to sustain it.¹²¹ Pearl translates the causal law into a mathematical formula:

W is in the following a set of variables which form part of a climate model, and let w, w' be specific realisations of these variables. The set of variable represents our (modelled) world u . We say that x causally sustains y in u relative to contingencies $W = w, w'$ if and only if

- (i) $X_{(u)} = x$;
- (ii) $Y_{(u)} = y$;
- (iii) $Y_{xw(u)} = y$ for all w ; and
- (iv) $Y_{x'w'(u)} = y' \neq y$ for some $x' \neq x$ and some w' .

¹¹⁹ Pearl (n 4) 316.

¹²⁰ *ibid* 309.

¹²¹ *ibid* 317; Rothman (n 19) 587.

The sustenance feature is represented in (iii). It means that x will maintain y even if we set W to any value w . (iv) explains that only x will sustain y . Thus, if we change x to x' , then Y will relinquish the current value y (we could also say the effect will change), for at least one setting of $W = w'$.¹²²

We define as follows:

$x=E$,

$Y=I_s$

W = a set of conditions, with w being variables of the set

U =our (modelled) world.

E is a cause if it will sustain I_s even if w will change. For instance, the fraction of the risk that is attributable to GHG emissions for the risk of flooding remains stable in proportion to the amount of GHG emissions, even if conditions (w) of the model are changed, such as improving flood protection measures. While the overall risk of flooding may change, the proportion of this risk that is produced by E remains the same. Only if we change E , for instance lower emissions, then there will be at least one set of conditions where I_s will change (the risk of flooding decreases).

This formula reflects the modelling used in probabilistic event attribution, where the divergence between counterfactual worlds and the actual world are simulated by changing contingency factors, such as changing emissions to measure the effect on the climate and the occurrence of climate related events. It can also be used in law, since it is based on logical fundamentals to which our legal concept can adapt. The reasoning based on necessity and sufficiency is extended

¹²² Pearl (n 4) 317.

by a further factor which accounts for a concurrent cause that produces the effect without being necessary or sufficient on its own.

A structural analysis using all three elements for the analysis can thus supply causal information derived from climate models. In our example case *Lhuiya*, the first step is to establish the causal link between E and I_F , in this case the concentration of GHG emissions in the atmosphere and the general increase in frequency and intensity of glacial ice loss. E can be identified as part of the component factors and the contribution to the risk can be quantified, based on the knowledge of the impact of E on glaciers within I_F , climate modelling and additional case-particularistic information.¹²³ A specific model could then be chosen to establish further case-particularistic evidence for the relation between E and I_S . Here, E may be one factor that forms part of a set of factors that cause the immediate risk, and if E is producing the proportional increase in risk for variations of other factors it is true to say that E sustains I_S . Further, only E will sustain I_S if a change of E (defined as a change from x to x' in step iv) will change our event I_S for at least one setting of conditions (w) in the climate model. The causal statement will at every stage include a reference to the fraction of the attributable risk for I_S and the confidence levels that is attached to the scientific evidence. Thus, much will depend on the availability of scientific evidence and the strength of this data varies for different climate related events and regions.

¹²³ Over an observation period from 1961 to 2016, global glacier mass changes cumulated to $-9,625 \pm 7,975$ Gt (1 Gt = 1012 kg), see for specific information and regions (including the Andes), Michael Zemp and others, 'Global glacier mass changes and their contributions to sea-level rise from 1961 to 2016' (2019) 568 Nature 382.

The advantage of the here presented formula is that this causal account does not stipulate an entire new counterfactual world in which no climate impacts exist. Conversely, it asserts that it is possible to structurally change some factors of the world which constitutes the model, and to see if the studied climate event is still maintained. This limits the counterfactual analysis to certain factors and the knowledge about the real world – and the type-level impacts that constitute the distinctive causal field can be used for the modelling. Sustenance establishes causation even if the anthropogenic increase in GHG concentrations represent only a (potentially small) part of a set of conditions.

In a further and final step, E can then be more narrowly defined as only the European Union's GHG emissions or the emissions of a major carbon emitter. On that basis, the concrete contribution of (a more narrowly defined) E can be quantified. The calculated fraction of the attributable climate risk to the defined emitter can be articulated in law: it is at least a concurrent cause.

4. Conclusion

This article has used elementary tools of formal logic to build a novel matrix of causally explaining the relation between GHG emissions and climate change impacts. We offer an approach that allows making causal statements in law about the physical reality of climate phenomena, side by side with probabilistic evidence that defines the relations between factors and events of our changing climate.

There is robust evidence that an equivalent causal relationship exists between the increase in GHG emissions due to the burning of fossil fuels and the increase in severity and frequency of certain severe weather and climate related events. These events constitute a distinctive causal

field. In addition to that, the property of sustenance is key to portraying the cause-quality of the anthropogenic emissions factor in a multistage scenario with several causes forming a set of conditions, where the mechanistic ‘but for’ or ‘conditio sine qua non’ tests would fail in finding a cause even though a factor contributed to the event; a situation for which case-specific normative correctives have not yet been developed. The novel matrix is thus based on necessity, sufficiency and sustenance.

We have demonstrated that based on this extended logical causal analysis, the concept of causation in law is compatible with scientific uncertainties and the complexity of anthropogenic climate change. Our approach of opening a seemingly strict causal test to include sustenance as a further analytical property, is based on the observation that normative correctives influence the identification of the ‘actual cause’ in other areas of law; in fact, pragmatic judicial reasoning surrounds the quest for causal explanations. Indeed, concentrating on causation as a pre-determined rigid concept is one of the greatest impediments for the legal response to climate change and law’s capacity to use scientific evidence. It limits options on adaptation and risk preparedness,¹²⁴ and it reduces the adjudicative capacity of courts.¹²⁵

Conversely, identifying legally meaningful causal explanations has several implications. It contributes, but is not limited, to building the adjudicative capacity of courts challenged by

¹²⁴ Peter Uhe and others, ‘Comparison of methods: Attributing the 2014 record European temperatures to human influences’ (2016) 43 *Geophysical Research Letters* 8685; see the predictions of future hydro-meteorological time series in the UK, Benoit Guillod and others, ‘A large set of potential past, present and future hydro-meteorological time series for the UK’ (2018) 22 *Hydrol Earth System Sci* 611, 629.

¹²⁵ IUCN World Congress on Environmental Law, Declaration on the Environmental Rule of Law, April 2016; Fisher and Scotford (n 15).

climate litigation. It also has a much wider impact for the potential of developing a ‘duty of care’ of GHG emitters and influencing future legal developments under the 2015 Paris Climate Agreement. Given that sufficient data will not be available for all climate related events and risks and those data are particularly limited in the most vulnerable countries, leaving causal explanations to be tested in courts alone raises ethical concerns such as equal access to justice. Thus, the legal-political realm might be well advised to utilise causal explanations *de lege ferenda*.