Extreme Climate Change

Daniel Bertram[1]

Climate change is one of the most important and acknowledged risks facing humanity (IPCC, 2022b). In assessing that risk, most discussions in science and policy focus on global mean warming in the range of 1.0 – 4.0°C above pre-industrial levels. While our odds of staying within that range have significantly improved over the past years (Meinshausen et al., 2022; IPCC, 2022a), even relatively moderate levels of warming imply drastic consequences for vulnerable groups and individuals (IPCC, 2022b). Nonetheless, these impacts would likely pale in comparison against the repercussions of extreme climate change.[2] Unfortunately, little sustained attention was devoted to extreme climate change for a long time (Jehn et al., 2021; King et al., 2015).[3] Only recently have researchers begun to study these risks in more depth (Hilton, 2022; Beard et al., 2021; Richards et al., 2021; Sandberg, 2019; Kareiva & Carranza, 2018; Ng, 2016). In contrast to other cause areas such as artificial intelligence or biotechnology, where the balance between opportunities and risks is often debated (see the respective sections in this research agenda), there is universal consensus that the negative impacts of extreme climate change would massively outweigh any positive side effects.[4] The choices of current generations in this matter will have definitive effects for millennia to come, elevating the urgency of short-term action (Clark et al., 2016).

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[2] 'Extreme' climate change does not have a clear definition. For the purposes of this chapter, I assume the term to encompass global average surface temperatures rising by more than 4°C, following the IPCC's finding that '[m]any global risks are high to very high for global temperature increases of 4°C or more' (IPCC, 2014, p. 65).

[3] In their analysis of the Summary for Policymakers of the IPCC's 2014 Fifth Assessment Report, the authors find that '[w]hile there are many mentions of impacts at 2°C and 4°C, there is only one mention of 5°C, and no mention of anything higher' (King et al., 2015, p. 45). The Sixth Assessment Report does mention, for instance, warming between 6.6°C and 14.1°C by the year 2300 under SSP5-8.5 (although only 'medium confidence' – that is, a 5 in 10 chance of the statement being correct – is placed in this still vast temperature range) (IPCC, 2021, s. TS1.1). For a comprehensive summary of the effects affiliated with a given degree of warming, seeLynas, 2020.

[4] I am grateful to Jeff Sebo for pointing out that it is less clear whether this statement holds true for non-human animals, too. Unless explicitly mentioned, the remainder of this chapter assumes an anthropocentric perspective for reasons of conciseness. For a detailed overview of longtermist concerns in animal law, see chapter X of this research agenda and Sebo, 2021.

Essentially, the manifestation of extreme climate change is a function of three elements, each of which is subject to high uncertainty (Ord, 2020, p. 182). First, we may simply fail to decrease anthropogenic greenhouse gas (GHG) emissions sufficiently (quickly) and continue to 'recklessly' burn fossil fuels until those resources are depleted.[5] Second, current climate models may be imprecise, and climate sensitivity to GHG emissions could be greater than assumed., i.e., the degree of warming at any given level of GHG concentration in the atmosphere could be larger than currently anticipated.[6] Third, although the speed and scale of global warming has directly aligned with the amount of anthropogenic GHG emissions so far, experts agree that this relationship could theoretically begin to disentangle in the future. Given the sheer complexity of the Earth's climate and ecosystems, and our limited understanding of their functioning, a rapid increase in temperatures may trigger rapid feedback loops. In the worst case scenario, these loops could spiral the Earth's system out of human control, irrespective of reductions in anthropogenic emissions (Ord, 2020, pp. 151–169; Richards et al., 2021). As Wunderling et al. (2021, p. 611) warn: 'Tipping cascades are first induced at warming levels around 1°C above pre-industrial GMT [global mean surface temperature], where the lower bound of the critical temperature range for the Greenland Ice Sheet is exceeded. The bulk of tipping cascades, however, is found between a 1 and 3°C GMT increase.' Overall, however, the risk resulting from such unknown unknowns is generally considered to be relatively limited for moderate warming scenarios (Hilton, 2022; Sherwood et al., 2020).

Considering these uncertainties, Toby Ord (2020) estimates the probability of human extinction as a result of anthropogenic global warming within the next 100 years at roughly 1 in 1000. Although he finds even extreme warming events of more than ten degrees Celsius unlikely to threaten human extinction directly, the limits of scientific knowledge surrounding the complex climate system reduce the confidence placed in that conclusion. While some debate continues, the direct extinction risk, or x-risk, potential of climate change is likely very small (Hilton, 2022; Richards et al., 2021).

[5] Given the current political climate, a 'recklessness' scenario seems unlikely (Meinshausen et al., 2022), but cannot be ruled entirely. The IPCC (2021) analyses five 'shared socio-economic pathways' to describe different emission scenarios.

[6] Economists used to worry over the 'fat tails' of probability distributions in many climate models, i.e., the low likelihood of extreme outcomes (Nordhaus, 2011; Weitzman, 2011). For a critical perspective on the usefulness of climate models more generally, see (Pindyck, 2017). The IPCC (2021, p. SPM-13) has recently made significant advances in assessing climate sensitivity, reducing the uncertainty arising from this parameter.

Next to the very small, but non-negligible threat of direct extinction, it currently seems much more likely that extreme shifts in climatic conditions entail serious risks of human suffering, or s-risks. For instance, according to recent estimates, excess temperature-related mortality due to extreme heat or extreme cold will almost certainly increase by the end of the century. The magnitude of this increase depends on the emissions pathway adopted and the availability of adaptation mechanisms such as air conditioning (Bressler et al. 2021). Other significant sources of suffering risk include sea level rise, droughts, extreme weather events and decreases in crop production, among others.[7] The direct vulnerabilities of human societies, and the extent to which adaptation could preclude enormous suffering, are still underexplored. For instance, how will a radically altered climate impact upon mental (Berry et al., 2010) and physical health (Haines et al., 2006)?

Extreme climate change's destructive potential could be exacerbated by its ability to increase the likelihood of other significant risks (Baum & Handoh, 2014; Richards et al., 2021). In this vein, climate change can be viewed as a stressor that compounds the vulnerability and exposure of our societies and decreases their overall resilience. Rather than triggering humanity's downfall with a loud bang, global warming may well become a 'boring apocalypse' (Liu et al., 2018). Some research suggests that both interpersonal and intergroup conflict increases in response to climatic changes (Hsiang et al., 2013; Nordås & Gleditsch, 2015).[8] To what extent could extreme forms of such changes apply to inter-state conflict? Similarly, climate-induced migration movements could fuel illiberal political forces in target countries and exacerbate the danger of a global authoritarian regime (Berlemann & Steinhardt, 2017; Hogan & Haltinner, 2015; Perch-Nielsen et al., 2008).[9] As climate change transforms ecosystems, there is also a danger that infectious diseases and natural pathogens will colonize new territories (Altizer et al., 2013). In

[7] For a more comprehensive list, see King et al., 2015.

[8] Other scholars are more skeptical of the 'threat multiplier' hypothesis and stress the social construction of and agency over climate vulnerabilities. Daoudy, 2021, p. 15: 'The climate–conflict nexus obfuscates causal processes that link environmental degradation and conflict.'

[9] Generally, the migration impacts of climate change seem to be relatively modest so far. An important caveat to this conclusion is that there is a dire lack of studies assessing the socio-economic effects of *extreme* forms of climate change.

general, knowledge about the more indirect ripple effects of extreme climate change on global societies is limited.[10]

Given this complex and variegated risk profile, what is the law's role in devising, regulating, and implementing adequate societal responses to extreme climate change? A survey of legal academics across the Anglophone world recently revealed that climate change is widely regarded as the most impactful issue area for the law to influence the far future (Martinez & Winter, 2021). In this chapter, I explore how exactly that legal potential could be exploited, while pointing to the many knowledge gaps plaguing the field. Since risks are typically conceptualized as a function of likelihood and impact, the following sections will explore research projects aimed at reducing the likelihood of extreme climate change through mitigation (X.1), and cushioning impacts through adaptation (X.2). Finally, I probe the role of overall resilience-building through the reduction of structural risks as a fruitful research area cutting across the mitigation/adaptation divide (X.3).

One way of thinking about the law's relation to extreme climate change foregrounds the notion of 'extremeness' (Sunstein, 2002). The core question here is whether reaching a given threshold ought to trigger a distinct set of legal and regulatory strategies (such as climate engineering interventions), or whether the ratcheting-up of pre-existing tools (such as carbon prices) is sufficient. In other words, do extreme scenarios of global warming call for a qualitative, rather than a quantitative shift in policy as compared to 'moderate' scenarios?[11] Given the lack of a definitive answer, I consider both distinctly 'extreme' legal strategies, i.e., those that may only become relevant once a certain threshold is breached, and 'regular' legal interventions aimed at preventing moderate and extreme forms of climate change alike.

Relatedly, the extreme nature of certain climatic scenarios introduces unique strategic choices and trade-offs. In a world of finite resources, the privileging of one or another strategy becomes indispensable, and indeed, inevitable, whether consciously or implicitly. For instance, one could

[10] William MacAskill has mentioned another interesting scenario: Societal collapse could materialize independent of climate change (e.g., through nuclear winter), with the persistent climatic effects of current emissions making the recovery from such an event impossible or exceedingly difficult. Presumably, preventing recovery in this way would be as bad as or even worse than inducing collapse, depending on one's expectations regarding humanity's capacity to bounce back.

[11] I am indebted to Arden Rowell for raising this issue.

argue that as GHG emission levels in the atmosphere rise, the regulatory and legal focus should move from emissions abatement toward adaptation, and eventually toward climate engineering. How should we go about making these trade-offs at a decision-theoretical level, and which legal, psychological, and political conditions influence that process? For instance, is it preferable to assess different legal strategies with the tools of expected value theory, or is a more risk-averse standard such as the precautionary principle or the 'maximin' principle appropriate (Sunstein, 2021; Rowell, 2020; Sunstein, 2009)? How does our bounded rationality compromise such balancing exercises (Wiener, 2016; Rowell & Bilz, 2021)?

X.1 Mitigating Extreme Climate Change

There are two pathways to minimizing the likelihood of extreme climate change. On the one hand, the concentration of GHG in the atmosphere should be stabilized and ultimately reduced[12] through decreasing and phasing out anthropogenic GHG emissions (X.1.1). On the other hand, technological interventions and climate engineering can artificially alter the climatic system to prevent or counteract global warming (X.1.2).[13]

Research Projects

X.1.1 Regulating Emissions Abatement

Emissions abatement has so far constituted the preferred policy approach to combat climate change. Reduction strategies and targets are enshrined in legal acts at international and national as well as local levels (Hilson, 2020). Although this topic has received a great deal of attention by legal scholars, there are significant methodological blind spots. Despite the exponential growth

[12] Greenhouse gasses eventually decompose in the atmosphere. When exactly this happens depends on the greenhouse gas. First, not all GHGs are created equal. Four different types of gasses are responsible for the greenhouse effect, all with varying potencies and lifecycles. Carbon dioxide, which makes up the largest share, degrades very slowly in the atmosphere, with as much as 10% persisting for 10,000 years or longer. Methane is some 84 times as potent as carbon dioxide over a 20-year period, but it disappears roughly after a decade. Nitrous oxide is even more potent than methane and persists for about a century. Fluorinated gasses can be many thousand times more potent than carbon dioxide, although their lifespans vary from gas to gas (Denchak, 2019). These facts bear important implications for policy (Allen et al., 2018).

[13] There is a dilemma arising out of this split between mitigation and technological intervention, in the sense that any advances in understanding the latter are seen to obstruct the former. For an exploration of the incentives required to overcome this dilemma, see Reynolds, 2021.

of climate law, extant studies have largely focussed on single case studies or small-N comparisons. Moreover, existing research has insufficiently engaged with rapidly advancing knowledge in other disciplines like economics,[14] and it has refused to approximate answers to overarching questions concerning effectiveness and efficiency (Mayer, 2018). Consequently, the state of legal emissions abatement scholarship is characterized by a lack of large-N comparative studies, literature reviews, quantitative and experimental methodologies, and interdisciplinary approaches, among others. How do different climate laws fare across jurisdictions in terms of effectiveness? Which variables influence the success of legal measures aimed at emissions reduction? How can experimental studies contribute to a better understanding of climate law design? To what extent does climate law influence policy outcomes in comparison with other social forces, such as market logics or cultural orientations?

X.1.1.1 Emissions Abatement in International Law

At the international level, as the latest international agreement on climate change, the 2015 Paris Agreement has been ratified by almost every state on the planet.[15] Having entered into force in 2016, it requires parties to submit nationally determined contributions (NDCs) with detailed GHG emissions reduction targets and plans to be given effect in domestic legislation. Owed to measurable advances in national climate legislation (Eskander & Fankhauser, 2020), the aggregate mitigation potential of NDCs is now broadly in line with the Paris goals (Meinshausen et al., 2022), closing earlier ambition gaps (Anderson et al., 2020; Lewis et al., 2019; Rogelj et al., 2016, Wunderling et al., 2021). How can this ambition be maintained? Is a reneging on previous commitments legal (Rajamani & Brunnée, 2017)? Is there an international legal obligation to mitigate against climate change at all (Mayer, 2019)? Unfortunately, not all NDCs are adequately transposed into national legislation or policy, and not all domestic climate laws and policies are effectively enforced as a matter of fact (Laudari et al., 2021). How can this implementation gap be closed? How can governments be held to their commitments? What is the role of subnational and private actors? What is the role for climate litigation in this regard (Wegener, 2020) (see also

[14] A laudable exception is the slightly dated article by (Heinzerling & Ackerman, 2007). A similar, more recent example of a study marrying insights from attribution science to law is (Stuart-Smith et al., 2021).
[15] As of late 2021, 192 states and the EU – covering about 98% of global GHG emissions – have ratified the Paris Agreement.

X.1.1.4)? And do we need a sort of 'regulatory fail-safe' that freezes all emissions once an agreed-upon threshold is passed?

X.1.1.2 Unilateral Emissions Abatement

Given the challenges of the international regime, high-impact research might continue to focus on countries with high GHG emissions like the US, China, or the EU bloc, as well as major future emitters such as India, Nigeria, Brazil, Indonesia, and others. In addition to these countries' direct contribution to global GHG emissions, their domestic policies can also have significant spill-over effects. These effects can be either positive, e.g., through reducing the cost of low-carbon technology globally, or negative, e.g., through 'carbon leakage', where carbon-intensive activities are outsourced to countries with laxer regulations. For instance, the heated debates on the so-called 'social cost of carbon' in US climate policy have proven to create significant global repercussions as other countries scramble to adopt the US standard, to the extent that it is sometimes termed 'the most important number you have never heard of' (Sunstein, 2022). The calculation of the social cost of carbon entails complex ethical, economic, and scientific considerations (Wagner et al., 2021). It is thus vulnerable to legal challenges, which have been forthcoming ever since President Biden's return to Obama-era policies in 2021 (Sunstein, 2022).[16] Whether, and by how much, the social cost of carbon should discount future damages is one of the key issues of contention (Fleurbaey et al., 2019; Fleurbaey & Zuber, 2012; Weitzmann, 1998). How can the US constitutional regime be (re-)designed to enable and protect the setting of low or negative discount rates (Sunstein, 2022)? More generally, how can law and policy in one country contribute to driving down global market prices for renewable energy technologies (Weinberger et al., 2020)? To what extent can carbon leakage be prevented through border carbon tax adjustments (Ismer & Neuhoff, 2007)? When may unilateral climate policy be justified under international law (Scott & Rajamani, 2012)?

X.1.1.3 Regulating the Energy Transition

The energy sector is currently the most GHG-intensive sector in highly industrialized economies. The law plays a special role in managing the transition from fossil-fuelled energy production to

[16] An updated calculation, putatively more stringent than the Obama-era numbers, is expected for late 2022.

renewable sources. The energy transition relies on the mainstreaming of climate policies across different areas of the law (Wildermuth, 2011). Land regulation is a particularly pertinent issue, given that the expansion of renewable energy infrastructure is currently severely curtailed by land law, often compounded by 'not in my backyard' attitudes (see, e.g., Gross, 2020). How can land regimes be reformed so as to enable and incentivize renewables? How should land use conflicts be dealt with? More generally, what are the implications of administrative and constitutional legal traditions for coordinating the energy transition (Saurer & Monast, 2021)? How should the law deal with the decommissioning of massive assets in fossil-fuel infrastructure (Heffron, 2018)? Which international legal frameworks are needed to allow for the cross-border exchange and supply of renewable energy? How can low-carbon innovation be incentivized through tax policy (Hart & Noll, 2019) and intellectual property regimes (Rimmer, 2011)? What is the impact of legal modalities on emission trading schemes' effectiveness (Bogojević, 2013; Villoria-Sáez et al., 2016)? Finally, how can regulatory hurdles to clean energy-production be eased while addressing the risks that may emanate from such technologies? One example is nuclear power, which plays an important role in the energy sector of several states and whose usage could increase drastically as fossil fuels are gradually abandoned. The underdevelopment of nuclear law seems to act as a constraint on the large-scale deployment of nuclear energy options (Sainati et al., 2019).

X.1.1.4 Food and Agriculture

Global food systems are responsible for one third of anthropogenic GHG emissions worldwide (Crippa et al., 2021). Despite its massive contribution to climate change, this sector seems to have received much less attention from legal scholars than energy, transport, or industry (see Angelo & du Plessis, 2017, for a laudable exception). As a result, a host of important legal questions are left unaddressed. A particularly impactful topic is the legal regulation of animal agriculture, given the latter's direct (e.g., through methane emissions) and indirect (e.g., through deforestation) contributions to GHG emissions. What legal levels can policymakers employ to phase down animal agriculture and phase up plant-based alternatives? How can the massive subsidies channeled towards agribusinesses – such as the EU's Common Agricultural Policy (Pe'er et al., 2019) – be brought in line with emissions abatement, for instance through international trade law and state aid rules? Should the international laws on agricultural and land use – currently spread out across various instruments such as the UNFCCC, the Convention on Biological Diversity, WTO law, and others – be consolidated into a single agreement?

X.1.1.5 Climate Litigation

Under what circumstances is climate litigation an effective tool to reduce emissions? The phenomenon of climate litigation has attracted the lion's share of attention among legal scholars, to the extent of exhibiting 'obsessive' qualities (Fisher, 2013). The actors engaging in such litigation are more diverse than ever, and the field has experienced not only rapid growth but also various shifts in substance (Setzer & Vanhala, 2019). The effectiveness of such litigation is still relatively unclear, however, as there is a lack of studies assessing causal hypotheses linking judicial victories to emissions reduction beyond anecdotal evidence. Important issues worthy of exploration concern the targeting of public vs. private actors (Ganguly et al., 2018), the legal bases most likely to succeed (Peel & Osofsky, 2018), evidentiary standards and materials (Stuart-Smith et al., 2021), the role of youth claimants as representatives of future generations (Bogojević, 2020), and the legitimacy of judge-made climate law (Burgers, 2020). What are the synergies between human/fundamental rights approaches to climate change (see also section X.3.1) and litigated action? For instance, in her dissent in the US Circuit Court's *Juliana* decision, Judge Staton argued that the US constitution contains a 'perpetuity principle' which entails 'a constitutional right to be free from irreversible and catastrophic climate change.'[17] How can the dangers of extreme warming – currently largely ignored – be made justiciable in climate litigation?

X.1.2 Geoengineering and Climate Engineering

The combination of increasing technological capacities to temper with the planet's climate and a growing sense of urgency might lead to the large-scale deployment of climate engineering in the mid-term future. Such interventions are often framed as an *ultima ratio* 'safety valve' should efforts to reduce emissions fail (Markusson et al., 2014). The evolving character of these technologies require flexible governance frameworks that capture the entire spectrum of likely instruments. Climate engineering currently comprises two main approaches. Solar radiation

[17] *Juliana v. United States*, 947 F.3d 1159, 1182 (9th Cir. 2020) (Staton, J., dissenting).

modification (SRM) is aimed at deflecting solar rays to prevent them from heating the atmosphere. Another approach, carbon dioxide removal (CDR) purports to extract CO2 from the atmosphere so as to reduce the greenhouse effect. Both technologies differ vastly in their current state of development, their ability to mitigate climate change, their geophysical impact, and the risks they entail (Gerrard & Hester, 2018). For instance, the deployment of CDR (such as reforestation) is less controversial and is partially relied upon by the Paris Agreement, whereas SRM technologies are in their infant stages of development and highly politicized, but not regulated explicitly.[18] Therefore, subsections X.1.2.1 and X.1.2.2 focus predominantly on SRM, whereas the regulation of CDR is addressed in X.1.2.3. A key concern regarding both SRM and CDR is the danger of moral hazard, i.e., the risk of a misguided belief in immature technological solutions crowding out urgent and necessary, but much more costly emissions abatement and climate adaptation (Larkin et al., 2018; Reynolds, 2021).

Overall, it is widely recognized that climate engineering could play an important role in mitigating against or even reversing anthropogenic climate change, but it that may also pose serious threats to humanity's wellbeing (Buck, 2019; Morton, 2015; Parson & Reynolds, 2021; Reynolds, 2019; Stephens et al., 2021; Zürn & Schäfer, 2013). An example of this is stratospheric aerosol injection (SAI), whereby the atmosphere is enriched with solar radiation-reflecting particles. While SAI harbors the potential to significantly counteract rampant climate change, there is an appreciable chance that it may be misappropriated for military purposes, or less malignly, simply fail to be furnished with the necessary global governance frameworks that would monitor and coordinate its safe execution (Biermann et al., 2022; Halstead, 2018, p. 75).[19] Similar issues affect other geoengineering technologies. A key concern here is the possibility of 'double catastrophe'. Many interventions require sustained and coordinated deployment over decades or centuries. Should an unrelated event (e.g., a pandemic) lead to social collapse and suddenly disrupt the geoengineering intervention, global warming could bounce back abruptly and prevent recovery from the initial catastrophe (Baum et al., 2013). In general, as will become clear,

[18] On the politicization of SRM, see Huttunen & Hildén, 2014; Kreuter, 2021; Oomen, 2021. Indeed, a group of experts and scientists recently issued an open call for a ban of all research and deployment of SRM, arguing that the risks of such technologies are unacceptable and ungovernable (Biermann et al., 2022). Nonetheless, SRM is widely considered a viable research avenue among most scientists (Dai et al., 2021).

[19] Halstead estimates these risks to be rather small, but stresses that 'we are arguably in a state of deep uncertainty'.

research on geoengineering is characterized by high levels of normative and empirical uncertainty (Oomen, 2021).

X.1.2.1 Regulating Research

The risks and benefits of many SRM interventions are highly unclear at this moment. This is because little to no deliberate, large-scale human interference with the climate system has taken place to date, and because our limited scientific understanding of complex earth systems makes accurate predictions prohibitively difficult. Clearly, more research is needed to generate a clearer picture of geoengineering's promise and pitfalls. Such studies, however, need to both inform and be guided by an effective governance regime (Parson & Keith, 2013; Wiener, 2016). Indeed, given the infant nature of many technologies at the moment, most legal regulation so far has focused on the effects of scientific research on, rather than deployment of, climate engineering. In addition, such regulation has overwhelmingly occurred at the domestic level, leading to a tapestry of national laws and policies (Burger & Gundlach, 2018; Lin, 2018). How do these various laws facilitate or constrain climate engineering research? Comparative methodologies appear particularly well-placed to answer this question. How can the legitimacy of outdoor research be maintained through inclusive public law frameworks?[20] To what extent does international law address the transboundary effects of outdoor research? Should there be an international agreement to coordinate geoengineering research? How might such an agreement best address various forms of current and future geoengineering techniques? Under what circumstance is technological restraint possible and desirable in the face of extreme scenarios?

X.1.2.2 Regulating Deployment

Concerns over the large-scale use of SRM technologies – despite the current improbability of such a scenario – necessitate the emergence of an institutional framework to govern deployment. Which institutional site is desirable to safeguard the legitimacy and effectiveness of decision-making? Given the global nature of the problem, the role of international law seems particularly pertinent. To what extent do or should the UNFCCC, the Paris Agreement, and/or

[20] The importance of the latter question was highlighted earlier in 2021 when a team of Harvard scientists had to call off a geoengineering project in Sweden over protests from local indigenous communities (Osaka, 2021).

the Convention on Biological Diversity address climate engineering (Williamson & Bodle, 2016)? Should a new international institution be created, and if so, how should it look like? What can we learn from the regulation of other technologies in this regard (Reynolds, 2014), and from comparison to other risks (Felgenhauer et al., 2022)? Or is SRM ungovernable and should be outlawed (Biermann et al., 2022)?

In terms of substance, there exists no authoritative agreement on the principles that should guide the use of climate engineering (Bodansky, 2013); instead, there are multiple competing soft law mechanisms. One of them are the five 'Oxford Principles' (Rayner et al., 2013), all of which raise a host of legal questions that urgently require further exploration. The Oxford Principles are an academic proposal, however, and there is serious debate as to their authority, specificity, sufficiency, and practical relevance. Other approaches such as the International Risk Governance Council's guidelines for emerging risk governance have been proposed (Grieger et al., 2019). Is this regulatory competition desirable, or does it lead to harmful gaps? Perhaps the most pressing question currently lies in how the law can facilitate entrepreneurial innovation whilst restricting private or decentralized deployment. To what extent should legal measures target non-state actors (Reynolds & Parson, 2020)? How could an SRM intervention, once deployed, be attributed to a single actor for liability purposes? Which rights and legal mechanisms are necessary for ensuring effective involvement of the citizenry at all stages of the intervention – and should the focus lie on international, national, or sub-national law? To what extent can the bulk of environmental law scholarship on impact assessments be transposed to a climate engineering context (Craik, 2015)? How might a liability and compensation scheme for harms arising from such interventions look like (Hester, 2018)?

X.1.2.3 Regulating Carbon Removal Technologies

CDR may become particularly attractive in extreme warming scenarios as a means of permanently returning GHG concentrations in the atmosphere to safer levels, whereas most SRM could only ever provide a temporally limited fix. In addition, the research and deployment of CDR is much less controversial than that of SRM, at least for the two most widely discussed and most promising interventions:[21] direct air capture and storage, and af-/reforestation.[22] Other technologies aimed at removing GHGs such as ocean fertilization are likely more risky, but they play only a marginal role in CDR policy so far (Kintisch, 2018). While af- and reforestation on enormous scales has been hailed by some as a high-impact, scalable CDR tool (Bastin et al., 2019), such highly optimistic projections claims have been severely criticized as inaccurate and inflated (Friedlingstein et al., 2019; Veldman et al., 2019). Opinions seem to converge that forestation can be a highly effective strategy in some ecological and social contexts, particularly for previously deforested areas in the tropics (Busch et al., 2019; Cerasoli et al., 2021; Nave et al., 2019). Among other fields, property law seems to play an important role in both de- and reforestation (Araujo et al., 2009; Legesse et al., 2018). How can this potential be harnessed to protect and increase the quantity and quality of forests? How can pledges to end global deforestation be enforced (Armao, 2022)? Should reforestation in high-impact areas for the global benefit be rewarded by the international community, and if so, what is the role of international law in that regard?[23] How can the deforestation impacts of economic activities be mainstreamed in trade and investment law, corporate law, and non-financial reporting obligations?

Regarding air capture and storage, it seems most fruitful for legal research to focus on ways of incentivizing the development of CDR, given that relatively few technologies are sufficiently mature for large-scale deployment. How can law most effectively incentivize development and diffusion of CDR technologies? What is the role of the law in creating long-term assurances in the use of CDR – that newly afforested forests are not all cut down, or that offset regimes involve actual additional net reductions? How can tax law support CDR development, as seen with the proposed 45Q tax credit bill in the US? Which intellectual property regime is most conducive to CDR (Rimmer, 2021)? How can states learn from each other to optimize CDR laws

[21] This applies for direct, predictable risks, but both forestation policies and air capture and storage can have unforeseen impacts on biodiversity and human rights that should be accounted for (Ryngaert, 2017).

[22] While deforestation denotes the clearing of forested land, afforestation is the process by which previously treeless areas are filled with new forests (in areas previously affected by deforestation, afforestation is often also called reforestation).

[23] One could imagine a scenario similar to the Yasunì-ITT Initiative, in which Ecuador asked the international community to compensate for parts of the costs of not exploiting an oil reserve (Vallejo et al., 2015). With regard to forest management, one could imagine multilateral contracts for reforestation projects in high-impact areas such as the tropics.

and policies (Arlota & de Medeiros Costa, 2021)? Is the Paris Agreement's reliance on large-scale CDR misguided (Larkin et al., 2018)?

Existing Academic Literature

Anderson, K., Broderick, J. F., & Stoddard, I. (2020). A factor of two: How the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways.*Climate Policy*, 20(10), 1290–1304. https://doi.org/10.1080/14693062.2020.1728209

Angelo, M. J., & Plessis, A. D. (2017). *Research Handbook on Climate Change and Agricultural Law*. Edward Elgar Publishing.

Baum, S. D., Maher, T. M., & Haqq-Misra, J. (2013). Double catastrophe: Intermittent stratospheric geoengineering induced by societal collapse. *Environment Systems & Decisions*, 33(1), 168–180. https://doi.org/10.1007/s10669-012-9429-y

Biermann, F., Oomen, J., Gupta, A., Ali, S. H., Conca, K., Hajer, M. A., Kashwan, P., Kotzé, L. J., Leach, M., Messner, D., Okereke, C., Persson, Å., Potočnik, J., Schlosberg, D., Scobie, M., & VanDeveer, S. D. (2022). Solar geoengineering: The case for an international non-use agreement. *WIREs Climate Change* e754. https://doi.org/10.1002/wcc.754

Bodansky, D. (2013). The who, what, and wherefore of geoengineering governance.*Climatic Change*, 121(3), 539–551. https://doi.org/10.1007/s10584-013-0759-7

Bodansky, D., Brunnée, J., & Rajamani, L. (2017). *International Climate Change Law*. Oxford University Press.

Buck, H. J. (2019). *After Geoengineering: Climate Tragedy, Repair, and Restoration*. Verso Books.

Clark, P. U., Shakun, J. D., Marcott, S. A., Mix, A. C., Eby, M., Kulp, S., Levermann, A., Milne, G. A., Pfister, P. L., Santer, B. D., Schrag, D. P., Solomon, S., Stocker, T. F., Strauss, B. H., Weaver, A. J., Winkelmann, R., Archer, D., Bard, E., Goldner, A., … Plattner, G.-K. (2016). Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. *Nature Climate Change*, 6(4), 360–369. https://doi.org/10.1038/nclimate2923

Cullenward, D., & Victor, D. G. (2020). *Making Climate Policy Work*. John Wiley & Sons.

Eskander, S. M. S. U., & Fankhauser, S. (2020). Reduction in greenhouse gas emissions from national climate legislation. *Nature Climate Change*, 10(8), 750–756. https://doi.org/10.1038/s41558-020-0831-z

Fleurbaey, M., & Zuber, S. (2012). Climate Policies Deserve a Negative Discount Rate. *Chicago Journal of International Law*, 13(2), 565–596.

Frame, D., & Allen, M. R. (2008). Climate change and global risk. In N. Bostrom & M. M. Cirkovic (Eds.), *Global Catastrophic Risks* (pp. 256–286). Oxford University Press.

Gerrard, M. B., & Hester, T. (Eds.). (2018). *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal*. Cambridge University Press.

Gowdy, J. (2020). Our hunter-gatherer future: Climate change, agriculture and uncivilization. *Futures*, 115, 102488. https://doi.org/10.1016/j.futures.2019.102488

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change*, 19(2), 240–247. https://doi.org/10.1016/j.gloenvcha.2008.12.003

Halstead, J. (2018). Stratospheric aerosol injection research and existential risk. *Futures*, 102, 63–77. https://doi.org/10.1016/j.futures.2018.03.004

Havercroft, I., & Purdy, R. (2007). Carbon Capture and Storage: Developments under European Union and International Law. *Journal for European Environmental & Planning Law*, 4(5), 353–366. https://doi.org/10.1163/187601007X00299

Heffron, R. J. (2018). Energy law for decommissioning in the energy sector in the 21st century. *The Journal of World Energy Law & Business*, 11(3), 189–195. https://doi.org/10.1093/jwelb/jwy013

Heyvaert, V. (2011). Governing Climate Change: Towards a New Paradigm for Risk Regulation. *The Modern Law Review*, 74(6), 817–844. https://doi.org/10.1111/j.1468-2230.2011.00874.x

Hilson, C. (2020). Hitting the Target? Analysing the Use of Targets in Climate Law. *Journal of Environmental Law*, 32(2), 195–220. https://doi.org/10.1093/jel/eqaa004

Holden, P. B., Edwards, N. R., Ridgwell, A., Wilkinson, R. D., Fraedrich, K., Lunkeit, F., Pollitt, H., Mercure, J.-F., Salas, P., Lam, A., Knobloch, F., Chewpreecha, U., & Viñuales, J. E. (2018). Climate–carbon cycle uncertainties and the Paris Agreement. *Nature Climate Change*, 8(7), 609–613. https://doi.org/10.1038/s41558-018-0197-7

IPCC. (2022a) *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

IPCC. (2022b) *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

Jehn, F. U., Schneider, M., Wang, J. R., Kemp, L., & Breuer, L. (2021). Betting on the best case: Higher end warming is underrepresented in research. *Environmental Research Letters*, 16(8), 084036. https://doi.org/10.1088/1748-9326/ac13ef

King, D., Schrag, D., Dadi, Z., Ye, Q., & Ghosh, A. (2015). *Climate Change: A Risk Assessment*. Cambridge Centre for Science and Policy. https://www.csap.cam.ac.uk/projects/climate-change-risk-assessment/

Klass, A. B., & Wilson, E. J. (2008). Climate Change and Carbon Sequestration: Assessing a Liability Regime for Long-Term Storage of Carbon Dioxide. *Emory Law Journal*, 58(1), 103–180.

Lawrence, P. (2015). *Justice for Future Generations: Climate Change and International Law*. Edward Elgar.

Lewis, B. (2018). The Rights of Future Generations within the Post-Paris Climate Regime. *Transnational Environmental Law*, 7(1), 69–87. https://doi.org/10.1017/S2047102517000243

Meinshausen, M., Lewis, J., McGlade, C., Gütschow, J., Nicholls, Z., Burdon, R., Cozzi, L., & Hackmann, B. (2022). Realization of Paris Agreement pledges may limit warming just below 2 °C. Nature, 604(7905), 304–309. https://doi.org/10.1038/s41586-022-04553-z

Minnerop, P. (2022). The 'Advance Interference-Like Effect' of Climate Targets: Fundamental Rights, Intergenerational Equity and the German Federal Constitutional Court. *Journal of Environmental Law* 34(1), 135–162. https://doi.org/10.1093/jel/eqab041

Narassimhan, E., Gallagher, K. S., Koester, S., & Alejo, J. R. (2018). Carbon pricing in practice: A review of existing emissions trading systems. *Climate Policy*, 18(8), 967–991. https://doi.org/10.1080/14693062.2018.1467827

Ng, Y.-K. (2016). The Importance of Global Extinction in Climate Change Policy. *Global Policy*, 7(3), 315–322. https://doi.org/10.1111/1758-5899.12318

Parson, E. A., & Reynolds, J. L. (2021). Solar geoengineering: Scenarios of future governance challenges. *Futures*, 133, 102806. https://doi.org/10.1016/j.futures.2021.102806

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., Bontzorlos, V., Clough, D., Bezák, P., Bonn, A., Hansjürgens, B., Lomba, A., Möckel, S., Passoni, G., Schleyer, C., Schmidt, J., & Lakner, S. (2019). A greener path for the EU Common Agricultural Policy. *Science*. https://doi.org/10.1126/science.aax3146

Pickering, J., McGee, J. S., Karlsson-Vinkhuyzen, S. I., & Wenta, J. (2019). Global Climate Governance Between Hard and Soft Law: Can the Paris Agreement's 'Crème Brûlée' Approach Enhance Ecological Reflexivity? *Journal of Environmental Law*, 31(1), 1–28. https://doi.org/10.1093/jel/eqy018

Rayner, S., Heyward, C., Kruger, T., Pidgeon, N., Redgwell, C., & Savulescu, J. (2013). The Oxford Principles. *Climatic Change*, 121(3), 499–512. https://doi.org/10.1007/s10584-012-0675-2

Reynolds, J. L. (2021). Is solar geoengineering ungovernable? A critical assessment of governance challenges identified by the Intergovernmental Panel on Climate Change. *WIREs Climate Change*, 12(2), e690. https://doi.org/10.1002/wcc.690

Rimmer, M. (2011). *Intellectual Property and Climate Change: Inventing Clean Technologies.* Edward Elgar Publishing.

Ryngaert, C. (2017). Climate Change Mitigation Techniques and International Law: Assessing the Externalities of Reforestation and Geoengineering. *Ratio Juris*, 30(3), 273–289. https://doi.org/10.1111/raju.12154

Scotford, E., & Minas, S. (2019). Probing the hidden depths of climate law: Analysing national climate change legislation. *Review of European, Comparative & International Environmental Law*, 28(1), 67–81. https://doi.org/10.1111/reel.12259

Scott, J., & Rajamani, L. (2012). EU Climate Change Unilateralism. European Journal of International Law, 23(2), 469–494. https://doi.org/10.1093/ejil/chs020

Setzer, J., & Vanhala, L. C. (2019). Climate change litigation: A review of research on courts and litigants in climate governance. WIREs Climate Change, 10(3), e580. https://doi.org/10.1002/wcc.580

Slobodian, L. (2019). Defending the Future: Intergenerational Equity in Climate Litigation. *Georgetown Environmental Law Review*, 32(3), 569–590.

Xu, Y., & Ramanathan, V. (2017). Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes. *Proceedings of theNational Academy of Sciences*, 114(39), 10315–10323. https://doi.org/10.1073/pnas.1618481114

Existing Informal Discussion

Bechtel, S. (2021, July 7). *The new EU climate law* [Blog Post]. Verfassungsblog. https://verfassungsblog.de/the-new-eu-climate-law/

Conn, A. (2019, August 1). *The Climate Crisis as an Existential Threat with Simon Beard and Haydn Belfield*. Future of Life Institute. https://futureoflife.org/2019/08/01/the-climate-crisis-as-an-existential-threat-with-simon-beard-and-haydn-belfield/?cn-reloaded=1

Dixon, L. (2019, April 17). *Does climate change deserve more attention within EA?* [Online Forum Post]. Effective Altruism Forum. https://forum.effectivealtruism.org/posts/BwDAN9pGbmCYZGbgf/does-climate-change-deserve-more-attention-within-ea

Hilton, B.. (2022, May 18). *Climate change: Is climate change the biggest threat facing humanity today?* 80,000 Hours. https://80000hours.org/problem-profiles/climate-change/

Ekardt, F. (2021, May 8). *Climate Revolution with Weaknesses* [Blog Post]. Verfassungsblog. https://verfassungsblog.de/climate-revolution-with-weaknesses/

Grantham Research Institute on Climate Change and the Environment (2022). *Climate Change Laws of the World*[Database]. https://climate-laws.org/

Halstead, J. (2019, March 23). *The case for delaying solar geoengineering research* [Online Forum Post]. Effective Altruism Forum. https://forum.effectivealtruism.org/posts/bKHjJBkfdHhA3SFJh/the-case-for-delaying-solar-geoengineering-research

Paris Peace Forum (2022). *Global Commission on Governing Risks from Climate Overshoot.* https://parispeaceforum.org/en/initiatives/global-commission-on-governing-risks-from-climate-overshoot/

Piper, K. (2019, June 13). *Is climate change an 'existential threat'—Or just a catastrophic one?* Vox. https://www.vox.com/future-perfect/2019/6/13/18660548/climate-change-human-civilization-existential-risk

Reynolds, J. & Irvine, P. (2022, January 11). *Challenging climate: Neal Stephenson on solar geoengineering and Termination Shock.* https://www.challengingclimate.org/1873533/9859141-neal-stephenson-on-solar-geoengineering-and-termination-shock

Sabin Center for Climate Change Law (2022a). *Carbon Dioxide Removal Law* [Database]. https://cdrlaw.org/

Sabin Center for Climate Change Law (2022b). [Database]. https://climate.law.columbia.edu/

Schwarte, F. (2021, May 27). *Should countries issue binding unilateral declarations on GHG emission targets?* [Blog Post]. Climate Law Blog. http://blogs.law.columbia.edu/climatechange/2021/05/27/should-countries-issue-binding-unilateral-declarations-on-ghg-emission-targets/

Stucki, S., Futhazar, G., Sparks, T., Tuchtfeld, E., & Foehr, H. (2021, September 7). *World Lawyers' Pledge on Climate Action: An Urgent Call for Climate Mainstreaming* [Blog Post]. EJIL: Talk! https://www.ejiltalk.org/world-lawyers-pledge-on-climate-action-an-urgent-call-for-climate-mainstreaming/

The Law Society (2021, February 18). *Climate change risks – the future of law as we know it?* https://www.lawsociety.org.uk/en/topics/research/climate-change-risks-the-future-of-law-as-we-know-it

X.2 Adapting to Extreme Climate Change

The importance of adaptation to climate change is contingent upon the extent to which mitigation efforts fail or succeed. Apparent shortcomings in mitigation strengthen the case for ambitious adaptation to worst-case scenarios, insofar possible. In light of current emissions trends, it is now widely recognized that adaptation must constitute a core pillar of climate policy to reduce vulnerabilities and exposures. Adaptation has the additional benefit of imposing fewer coordination costs, since adaptation efforts are excludable goods and individuals, communities, and countries thus have strong incentives to engage in such measures regardless of others' commitments. Despite these advantages, there are biophysical and social limits to adaptation (Dow et al., 2013). Generally, there is little scientific thinking around how adaptation to extreme warming scenarios could look like (this task is often left to fiction writers) and even less writing on the role of legal research in this endeavor.

Adaptation can take many forms, ranging from incremental (e.g., switching to slightly different crops) to disruptive (e.g., climate-induced migration) (Adger et al., 2005). While these forms correspond with and engage different legal sectors and scales (Craig, 2010; McDonald, 2011), there are several larger ethical and pragmatic questions guiding the design of adaptation laws (Driessen & Rijswick, 2011): Which societal interests should be prioritized and protected through adaptation (Wenta et al., 2019)? Should climate adaptation law be seen as a distinct field (Ruhl & Salzman, 2012)? How much room for discretion should adaptation legislation leave, and who is best entrusted with this discretion – national executives, local and regional government, private actors? Which climatic scenarios should legal adaptation efforts take into account? To what extent should adaptation respond to circumscribed risks or aim to contribute to overall resilience (see also section X.3 on structural risks)?

In international law, adaptation occupies a prominent position in Article 7 of the Paris Agreement, which sets out guiding principles of adaptation policy – including its 'effectiveness' and 'durability' as well as coordination mechanisms. Troublingly, despite this commitment to durability, the time horizons of many adaptation efforts have been rather limited so far (Garschagen et al., 2021). Changes in collective and individual human behavior will require legal regimes that enable and incentivize adaptive conduct against the backdrop of rampant present bias and irrational discounting of future risks. How might property rights be (re-)structured to account for massive shifts in land use? How should national and international migration and refugee law deal with those displaced by climatic changes (Behrman & Kent, 2018; McAdam, 2012)? How can regulations incentivize the conservation of biological and cultural resources in a radically hotter planet, for instance in secure seed banks (Patel, 2017; Vernooy et al., 2017)? To what extent can legislation enhance flood resilience (Mehryar & Surminski, 2021)? Who is to pay for the immense costs of climate change adaptation measures?[24] How can climate adaptation laws be designed to include and protect the wellbeing of non-human animals, many of which are extremely vulnerable to climatic changes (Sebo, 2021)?

Existing Academic Literature

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change*, 15(2), 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Bendell, J. (2018). *Deep adaptation: A map for navigating climate tragedy* [Report]. University of Cumbria. http://www.lifeworth.com/deepadaptation.pdf

Craig, R. K. (2010). Stationarity is Dead - Long Live Transformation: Five Principles for Climate Change Adaptation Law. *Harvard Environmental Law Review*, 34(1), 9–74.

Dow, K., Berkhout, F., Preston, B. L., Klein, R. J. T., Midgley, G., & Shaw, M. R. (2013). Limits to adaptation. *Nature Climate Change*, 3(4), 305–307. https://doi.org/10.1038/nclimate1847

Driessen, P. P. J., & Rijswick, H. F. M. W. van. (2011). Normative aspects of climate adaptation policies. *Climate Law*, 2(4), 559–581. https://doi.org/10.1163/CL-2011-051

Garschagen, M., Doshi, D., Moure, M., James, H., & Shekhar, H. (2021). The consideration of future risk trends in national adaptation planning: Conceptual gaps and empirical lessons. *Climate Risk Management*, 34, 100357. https://doi.org/10.1016/j.crm.2021.100357

Mees, H. L. P., Driessen, P. P. J., & Runhaar, H. A. C. (2012). Exploring the Scope of Public and Private Responsibilities for Climate Adaptation. *Journal of Environmental Policy & Planning* 14(3), 305–330. https://doi.org/10.1080/1523908X.2012.707407

Mehryar, S., & Surminski, S. (2021). National laws for enhancing flood resilience in the context of climate change: Potential and shortcomings. *Climate Policy*, 21(2), 133–151. https://doi.org/10.1080/14693062.2020.1808439

[24] For instance, in the German *Huaraz* litigation a Peruvian claimant whose property is threatened by the climate-induced growth in volume of a nearby glacial lake sued German energy giant RWE in order to recover adaptation costs proportionate to the latter's share in historic GHG emissions. The case is currently pending on appeal, but a first interlocutory ruling in 2017 clearly showed the court's inclination to follow this line of argumentation (Frank et al., 2019). Given that a relatively small, clearly identifiable number of large emitters are responsible for the vast majority of historic global GHG emissions, similar legal disputes may soon feature center stage in adaptation discourse.

Parker-Flynn, J. E. (2014). The Intersection of Mitigation and Adaptation in Climate Law and Policy. *Environs: Environmental Law and Policy Journal*, 38(1), 1–48.

Ruhl, J. B., & Salzman, J. (2012). Climate change Meets the Law of the Horse. *Duke Law Journal*, 62(5), 975–1028.

Vernooy, R., Sthapit, B., Otieno, G., Shrestha, P., & Gupta, A. (2017). The roles of community seed banks in climate change adaption. *Development in Practice*, 27(3), 316–327. https://doi.org/10.1080/09614524.2017.1294653

Wenta, J., McDonald, J., & McGee, J. S. (2019). Enhancing Resilience and Justice in Climate Adaptation Laws. *Transnational Environmental Law*, 8(1), 89–118. https://doi.org/10.1017/S2047102518000286

Existing Informal Discussion

Adler, D. (2019, January 16). *Will new litigation pressure energy and industrial infrastructure to prepare for climate change?* [Blog Post]. Climate Law Blog. http://blogs.law.columbia.edu/climatechange/2019/01/16/will-new-litigation-pressure-energy-industrial-infrastructure-to-prepare-for-climate-change/

Gerrard, M. B. (2019, December 5). *12 legal tools to push climate preparedness* [Blog Post]. Climate Law Blog. http://blogs.law.columbia.edu/climatechange/2019/12/05/12-legal-tools-to-push-climate-preparedness/

World Food Programme (2022). *Climate change adaptation*. https://www.wfp.org/climate-change-adaptation

X.3 Reducing Structural Risks

The impact of extreme climate change on other serious risks poses great threats to the flourishing of life (Beard et al., 2021). These knock-on effects have led Kuhlemann to classify the climate crisis as an 'unsexy risk' with no epistemically neat boundaries, direct lines of causation and clearly identifiable outcomes (Kuhlemann, 2018). Following the categorization elaborated by Liu, Lauta and Maas (2018), extreme climate change is mostly treated as a hazard, while its harm potential is crucially exacerbated by our social vulnerabilities and exposures (IPCC, 2022b).

Against this backdrop, how can the law contribute to boosting social resilience beyond addressing specific risks (Kreienkamp & Pegram, 2020)? Many fruitful research projects that could also cushion the indirect, knock-on effects of extreme climate change are explored in other chapters of this research agenda. In the following, I sketch two research areas that appear particularly relevant to combat structural climate risks: the creation of long-term institutions tasked with a holistic approach to existential and catastrophic risks (see also chapter 7 on institutional design), and reducing intragenerational inequality.

X.3.1 Institutional Design[25]

While both mitigation and adaptation play a crucial role in reducing the risk of extreme climate change by addressing its likelihood and impact, respectively, institutional transformations provide the ultimate legal lever for long-term climate action. In contrast to other pressing global challenges like artificial intelligence or synthetic biology, climate risks arise directly from the very structures that sustain our global political economy. It does not require an accident, malicious intent, or reckless behavior for the risk to materialize – instead, it feeds on a deeply embedded systemic logic, whose language is first and foremost legal. As David Kennedy reminds us, '[l]aw not only *regulates* these things, it creates them', implying that '[t]he history of political and economic life is therefore also a history of institutions and laws' (Kennedy, 2013, p. 8). Accordingly, law also possesses the power to effectuate paradigm changes toward sustainability.

Climate change is a collective action problem that is both intragenerational, i.e., between members of a single generation (but often pertaining to different nations and different socio-economic classes), as well as intergenerational. The groups most responsible – past and present generations of the upper echelons of wealthy nations in the global north (Nielsen et al., 2021; Timperley, 2020) – differ significantly from the groups most affected. This means that the overarching Herculean challenge facing all climate law resides in achieving targets in a manner that is simultaneously equitable, efficient, and effective. There is a dire lack of knowledge on different legal approaches' performance across these three categories. This gives rise to several

[25] Many observations made here overlap to a large degree with those made in chapter X on institutional design. I therefore restrict myself to highlighting some of the most urgent questions specific to climate change, cognizant of the fact that larger structural changes such as extending legal representation to non-nationals and future generations may be just as or more impactful.

urgent overarching research questions, in addition to the more specific projects outlined above. For instance, who should be targeted by climate law,[26] and, conversely, which areas of the law provide a particularly attractive lever to minimize emissions? Which legal instrument should be adopted under which conditions – 'hard' or 'soft' law obligations such as emission caps,[27] carbon pricing,[28] private duties of care,[29] criminal liability,[30] or nudging,[31] just to name a few? Which institutional site – legislative, executive, judicial, or private – and level – international, national, or regional/local – of legal norm-generation is preferable to act on climate change in a given context?[32] What is the role of constitutional law in shaping climatic trajectories? For instance, to what extent should criminal and constitutional law facilitate acts of civil disobedience and sabotage in protesting against the climate crisis (Malm, 2021)?

In terms of distinctly legal institutional responses, there is a growing tendency to frame responses to (extreme) climate change in terms of human rights (Wewerinke-Singh, 2019; Peel & Osofsky, 2018; Bodansky, 2010; Humphreys, 2010). How can the 'universal grammar' of human rights support holistic approaches to structural climate risks? Which human rights would be violated by state actions and omissions regarding extreme climate change? Is the right to a healthy environment an adequate legal framework when it comes to extreme climate change, or should international law codify a specific right to 'climate stability'? To what extent can rights be invoked in climate litigation, and by whom? What are the limits of the rights frame for addressing extreme climate change (Mayer, 2021)?

[26] Similar to agential risks in other cause areas (Kemp, 2021), relatively few actors are responsible for the vast majority of GHG emissions, including a handful of states and several mighty corporations, see, e.g.Evans, 2021; Heede, 2014.
[27] For inroads into this discussion, see Pickering et al., 2019; Vihma, 2013.
[28] How can legal regulation incorporate the work of economists and philosophers on carbon pricing (Boyce, 2018; Fleurbaey et al., 2019; Narassimhan et al., 2018)? Note that while the desirability of carbon pricing is almost universally shared, its feasibility and implementation are fiercely disputed (Cullenward & Victor, 2020).
[29] Tort law presents a particularly interesting example, see Kysar, 2011.
[30] See, e.g. Tucker, 2012.
[31] Nudging exploits a number of shortcuts and heuristics in human cognition, much like corporate advertising does, in order to better align human behavior with climate policies (Colasante et al., 2021; Hagmann et al., 2019; Lehner et al., 2016).
[32] For instance, there seems to exist a fragile consensus that strengthening the interaction between different regulatory scales and actors is more effective in driving down emissions than unilateral, unilevel, or uniform approaches (Dorsch & Flachsland, 2017; Jordan et al., 2015; Ostrom, 2010). On the contribution of local and regional actors, see Anderton & Setzer, 2018; Richardson, 2012.

Financial flows are currently poorly aligned with priorities identified by climate policy research (Halstead & Ackva, 2020). How can legal tools improve this alignment? For instance, Broome and Foley have argued for the establishment of a new institution, a World Climate Bank, to facilitate intergenerational climate action (Broome & Foley, 2016). What is the role of corporate law (Wallace, 2009) and climate-related disclosure obligations (Demaria & Rigot, 2021) in inducing and facilitating organizational sensibilization toward climatic changes?

X.3.2 Reducing Inequality

Along with myriad specific vulnerabilities that contribute to climate risk (think of the proximity of major parts of the population to the sea, for instance), there is one obvious social vulnerability that could greatly constrain our ability to confront extreme global warming: the glaring socio-economic inequality present at both national and global levels. Contrary to established tropes framing inequality reduction and ambitious climate action as conflicting goals, empirical studies actually suggest that decreased inequality does not raise emissions (Taconet et al., 2020).[33] Instead, there are indications that current levels of inequality inhibit effective climate risk policy across all three categories laid out in this chapter: mitigation, adaptation, and structural risk (Burton-Chellew et al., 2013; Dennig et al., 2015; Pelling & Garschagen, 2019; Taconet et al., 2020).

On the one hand, numerous studies have warned that the impacts of extreme climate change are and will be felt particularly acutely by socially and economically underprivileged populations (Ahmadalipour et al., 2019; Thornton et al., 2014; Sherwood & Huber, 2010;), raising the danger of internal and international conflict and geopolitical tensions (Baten & Mumme, 2013; Schmidt & Juijn, 2021), which may in turn weaken the global response to climatic changes or other risks. On the other hand, countries' contribution to and potential to mitigate extreme climate change differ drastically. How can the law lessen these inequalities in vulnerability and impact? Conversely, how may regulation approach the distribution of the enormous benefits concomitant of averting extreme warming (Rowell, 2020)?

[33] See also Rao & Min, 2018, p. 4: '[A]ggressive reductions in between-country inequality may decrease the emissions intensity of global economic growth, due to the higher potential for decoupling of energy from income growth in lower income countries.'

The idea of equitable burden-sharing lies at the center of climate justice and its legal articulations (Jones, 2018; Lyster, 2016; Okereke & Coventry, 2016). In international law, the principle of 'common but differentiated responsibilities' enshrines the differential approach to climate action that takes historical and ongoing inequalities into account (Rajamani, 2012), but most countries fall significantly short of contributing their 'fair share' (Rajamani et al., 2021). How can considerations of fairness be mainstreamed in climate policy? Legal frameworks also play a crucial role in softening the disparate impacts of climate-induced disasters (Lyster & Verchick, 2018). In addition, some climate policies – most notably, biofuel production (Baka, 2014) and forestry protection (Suiseeya, 2017) – can have a discriminatory effect on socially disadvantaged groups and deepen existing crevasses (Markkanen & Anger-Kraavi, 2019), thereby exacerbating conflict risks (Work, 2019). The design of such laws must therefore explicitly factor in social side effects.

Existing Academic Literature

Broome, J., & Foley, D. K. (2016). A World Climate Bank. In I. Gónzalez-Ricoy & A. Gosseries (Eds.), *Institutions for Future Generations*. Oxford University Press.

Brown Weiss, E. (2007). Climate Change, Intergenerational Equity, and International Law. *Vermont Journal of Environmental Law*, 9(3), 615–628.

Burton-Chellew, M. N., May, R. M., & West, S. A. (2013). Combined inequality in wealth and risk leads to disaster in the climate change game. *Climatic Change*, 120(4), 815–830. https://doi.org/10.1007/s10584-013-0856-7

Choudhury, B. (2020). *Climate Change as Systemic Risk* (SSRN Scholarly Paper ID 3704962). Social Science Research Network. https://doi.org/10.2139/ssrn.3704962

Doelle, M., & Seck, S. (2020). Loss & damage from climate change: From concept to remedy? Climate Policy, 20(6), 669–680. https://doi.org/10.1080/14693062.2019.1630353

Gonzalez‐Ricoy, I., & Rey, F. (2019). Enfranchising the future: Climate justice and the representation of future generations. *WIREs Climate Change*, 10(5), e598. https://doi.org/10.1002/wcc.598

Hayward, T. (2007). Human Rights Versus Emissions Rights: Climate Justice and the Equitable Distribution of Ecological Space. *Ethics & International Affairs*, 21(4), 431–450. https://doi.org/10.1111/j.1747-7093.2007.00117.x

Heyvaert, V. (2011). Governing Climate Change: Towards a New Paradigm for Risk Regulation. *The Modern Law Review*, 74(6), 817–844. https://doi.org/10.1111/j.1468-2230.2011.00874.x

Hovi, J., Sprinz, D. F., & Underdal, A. (2009). Implementing Long-Term Climate Policy: Time Inconsistency, Domestic Politics, International Anarchy. *Global Environmental Politics*, 9(3), 20–39. https://doi.org/10.1162/glep.2009.9.3.20

Humphreys, S. (Ed.). (2010). *Human Rights and Climate Change*. Cambridge University Press.

Knox, J. H. (2009). Climate Change and Human Rights Law. *Virginia Journal of International Law*, 50(1), 163–218.

Lyster, R., & Verchick, R. (2018). *Research Handbook on Climate Disaster Law*. Edward Elgar Publishing.

Lomborg, B. (2020). Welfare in the 21st century: Increasing development, reducing inequality, the impact of climate change, and the cost of climate policies. *Technological Forecasting and Social Change*, 156, 119981. https://doi.org/10.1016/j.techfore.2020.119981

Martin, S. (2010). Climate Change, Migration, and Governance. *Global Governance*, 16(3), 397–414.

McAdam, J. (2012). *Climate Change, Forced Migration, and International Law*. OUP Oxford.

Parthemore, C., Femia, F., & Werrell, C. (2018). The global responsibility to prepare for intersecting climate and nuclear risks. *Bulletin of the Atomic Scientists*, 74(6), 374–378. https://doi.org/10.1080/00963402.2018.1533186

Richards, C. E., Lupton, R. C., & Allwood, J. M. (2021). Re-framing the threat of global warming: An empirical causal loop diagram of climate change, food insecurity and societal collapse. *Climatic Change*, 164(3), 49. https://doi.org/10.1007/s10584-021-02957-w

Ryngaert, C. (2017). Climate Change Mitigation Techniques and International Law: Assessing the Externalities of Reforestation and Geoengineering. *Ratio Juris*, 30(3), 273–289. https://doi.org/10.1111/raju.12154

Sebo, J. (2021). Animals and Climate Change. In M. Budolfson, T. McPherson, & D. Plunkett (Eds.), *Philosophy and Climate Change*. Oxford University Press.

Existing Informal Discussion

Basel Committee on Banking Supervision (2021). *Climate-related risk drivers and their transmission channels* [Report]. https://www.bis.org/bcbs/publ/d517.pdf

Coursen, D. (2021, November 6). *Climate change imperils critical infrastructure*. The Hill. https://thehill.com/opinion/energy-environment/580388-climate-change-imperils-critical-infrastructure

Nevitt, M. (2020, August 29). *Climate change: A threat to international peace & security?* [Blog Post]. Opinio Juris. http://opiniojuris.org/2020/08/29/climate-change-a-threat-to-international-peace-security/

Smolénska, A. & van't Klooster, J. (2020, November 16). *Greening banks in the face of uncertainty* [Blog Post]. Verfassungsblog. https://verfassungsblog.de/greening-banks-in-the-face-of-uncertainty/

United Nations Environment Programme (2022). Climate change and security risks. https://www.unep.org/explore-topics/disasters-conflicts/what-we-do/disaster-risk-reduction/climate-change-and-security

Bibliography

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change*, *15*(2), 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Ahmadalipour, A., Moradkhani, H., Castelletti, A., & Magliocca, N. (2019). Future drought risk in Africa: Integrating vulnerability, climate change, and population growth. *Science of The Total Environment*, *662*, 672–686. https://doi.org/10.1016/j.scitotenv.2019.01.278

Allen, M. R., Shine, K. P., Fuglestvedt, J. S., Millar, R. J., Cain, M., Frame, D. J., & Macey, A. H. (2018). A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. *Npj Climate and Atmospheric Science*, *1*(1), 1–8. https://doi.org/10.1038/s41612-018-0026-8

Altizer, S., Ostfeld, R. S., Johnson, P. T. J., Kutz, S., & Harvell, C. D. (2013). Climate Change and Infectious Diseases: From Evidence to a Predictive Framework. *Science*, *341*(6145), 514–519. https://doi.org/10.1126/science.1239401

Anderson, K., Broderick, J. F., & Stoddard, I. (2020). A factor of two: How the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways.*Climate Policy*, *20*(10), 1290–1304. https://doi.org/10.1080/14693062.2020.1728209

Anderton, K., & Setzer, J. (2018). Subnational climate entrepreneurship: Innovative climate action in California and São Paulo. *Regional Environmental Change*, *18*(5), 1273–1284. https://doi.org/10.1007/s10113-017-1160-2

Angelo, M. J., & Plessis, A. D. (2017). *Research Handbook on Climate Change and Agricultural Law*. Edward Elgar Publishing.

Araujo, C., Bonjean, C. A., Combes, J.-L., Combes Motel, P., & Reis, E. J. (2009). Property rights and deforestation in the Brazilian Amazon. *Ecological Economics*, *68*(8), 2461–2468. https://doi.org/10.1016/j.ecolecon.2008.12.015

Arlota, C., & de Medeiros Costa, H. K. (2021). Who is taking climate change seriously? Evidence based on a comparative analysis of the carbon capture and storage national legal framework in Brazil, Canada, the European Union, and the United States. In H. K. de Medeiros Costa & C. Arlota (Eds.), *Carbon Capture and Storage in International Energy Policy and Law* (pp. 235–246). Elsevier. https://doi.org/10.1016/B978-0-323-85250-0.00018-9

Armao, M. (2022, January 18). The majority of the world promised to end deforestation. But businesses are standing in the way. *Grist*. https://grist.org/article/the-majority-of-the-world-promised-to-end-deforestation-but-businesses-are-standing-in-the-way/

Baka, J. (2014). What wastelands? A critique of biofuel policy discourse in South India. *Geoforum*, *54*, 315–323. https://doi.org/10.1016/j.geoforum.2013.08.007

Bastin, J.-F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D., Zohner, C. M., & Crowther, T. W. (2019). The global tree restoration potential. *Science*, *365*(6448), 76–79. https://doi.org/10.1126/science.aax0848

Baten, J., & Mumme, C. (2013). Does inequality lead to civil wars? A global long-term study using anthropometric indicators (1816–1999). *European Journal of Political Economy*, *32*, 56–79. https://doi.org/10.1016/j.ejpoleco.2013.06.007

Baum, S. D., & Handoh, I. C. (2014). Integrating the planetary boundaries and global catastrophic risk paradigms. *Ecological Economics*, *107*, 13–21. https://doi.org/10.1016/j.ecolecon.2014.07.024

Baum, S. D., Maher, T. M., & Haqq-Misra, J. (2013). Double catastrophe: Intermittent stratospheric geoengineering induced by societal collapse. *Environment Systems & Decisions*, *33*(1), 168–180. https://doi.org/10.1007/s10669-012-9429-y

Beard, S. J., Holt, L., Tzachor, A., Kemp, L., Avin, S., Torres, P., & Belfield, H. (2021). Assessing climate change's contribution to global catastrophic risk. *Futures*, *127*, 102673. https://doi.org/10.1016/j.futures.2020.102673

Behrman, S., & Kent, A. (Eds.). (2018). *Climate Refugees: Beyond the Legal Impasse?* Routledge.

Berlemann, M., & Steinhardt, M. F. (2017). Climate Change, Natural Disasters, and Migration—A Survey of the Empirical Evidence. *CESifo Economic Studies*, *63*(4), 353–385. https://doi.org/10.1093/cesifo/ifx019

Berry, H. L., Bowen, K., & Kjellstrom, T. (2010). Climate change and mental health: A causal pathways framework. *International Journal of PublicHealth*, *55*(2), 123–132. https://doi.org/10.1007/s00038-009-0112-0

Biermann, F., Oomen, J., Gupta, A., Ali, S. H., Conca, K., Hajer, M. A., Kashwan, P., Kotzé, L. J., Leach, M., Messner, D., Okereke, C., Persson, Å., Potočnik, J., Schlosberg, D., Scobie, M., & VanDeveer, S. D. (2022). Solar geoengineering: The case for an international non-use agreement. *WIREs Climate Change*, *n/a*(n/a), e754. https://doi.org/10.1002/wcc.754

Bodansky, D. (2010). Introduction: Climate Change and Human Rights: Unpacking the Issues. *Georgia Journal of International and Comparative Law*, 38(3), 511–524.

Bodansky, D. (2013). The who, what, and wherefore of geoengineering governance. *Climatic Change*, *121*(3), 539–551. https://doi.org/10.1007/s10584-013-0759-7

Bogojević, S. (2013). *Emissions Trading Schemes: Markets, States and Law*. Hart Publishing. https://doi.org/10.5040/9781474200110

Bogojević, S. (2020). Human rights of minors and future generations: Global trends and EU environmental law particularities. *Review of European, Comparative & International Environmental Law*, *29*(2), 191–200. https://doi.org/10.1111/reel.12345

Boyce, J. K. (2018). Carbon Pricing: Effectiveness and Equity. *Ecological Economics*, *150*, 52–61. https://doi.org/10.1016/j.ecolecon.2018.03.030

Bressler, R. D., Moore, F. C., Rennert, K., & Anthoff, D. (2021). Estimates of country level temperature-related mortality damage functions. *Scientific Reports, 11*(1), 20282. https://doi.org/10.1038/s41598-021-99156-5

Broome, J., & Foley, D. K. (2016). A World Climate Bank. In I. Gónzalez-Ricoy & A. Gosseries (Eds.), *Institutions for Future Generations*. Oxford University Press.

Buck, H. J. (2019). *After Geoengineering: Climate Tragedy, Repair, and Restoration*. Verso Books.

Burger, M., & Gundlach, J. (2018). Research Governance. In M. B. Gerrard & T. Hester (Eds.), *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal* (pp. 269–323). Cambridge University Press. https://doi.org/10.1017/9781316661864.006

Burgers, L. (2020). Should Judges Make Climate Change Law? *Transnational Environmental Law*, *9*(1), 55–75. https://doi.org/10.1017/S2047102519000360

Burton-Chellew, M. N., May, R. M., & West, S. A. (2013). Combined inequality in wealth and risk leads to disaster in the climate change game. Climatic Change, 120(4), 815–830. https://doi.org/10.1007/s10584-013-0856-7

Busch, J., Engelmann, J., Cook-Patton, S. C., Griscom, B. W., Kroeger, T., Possingham, H., & Shyamsundar, P. (2019). Potential for low-cost carbon dioxide removal through tropical reforestation. *Nature Climate Change*, *9*(6), 463–466. https://doi.org/10.1038/s41558-019-0485-x

Cerasoli, S., Yin, J., & Porporato, A. (2021). Cloud cooling effects of afforestation and reforestation at midlatitudes. *Proceedings of theNational Academy of Sciences*, *118*(33). https://doi.org/10.1073/pnas.2026241118

Clark, P. U., Shakun, J. D., Marcott, S. A., Mix, A. C., Eby, M., Kulp, S., Levermann, A., Milne, G. A., Pfister, P. L., Santer, B. D., Schrag, D. P., Solomon, S., Stocker, T. F., Strauss, B. H., Weaver, A. J., Winkelmann, R., Archer, D., Bard, E., Goldner, A., … Plattner, G.-K. (2016). Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. *Nature Climate Change*, *6*(4), 360–369. https://doi.org/10.1038/nclimate2923

Colasante, A., D'Adamo, I., & Morone, P. (2021). Nudging for the increased adoption of solar energy? Evidence from a survey in Italy. *Energy Research & Social Science*, *74*, 101978. https://doi.org/10.1016/j.erss.2021.101978

Craig, R. K. (2010). Stationarity is Dead - Long Live Transformation: Five Principles for Climate Change Adaptation Law. *Harvard Environmental Law Review*, *34*(1), 9–74.

Craik, N. (2015). International EIA Law and Geoengineering: Do Emerging Technologies Require Special Rules? *Climate Law*, *5*(2–4), 111–141. https://doi.org/10.1163/18786561-00504002

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198–209. https://doi.org/10.1038/s43016-021-00225-9

Cullenward, D., & Victor, D. G. (2020). *Making Climate Policy Work*. John Wiley & Sons.

Cullinan, C. (2011). *Wild Law*. Siber Ink.

Dai, Z., Burns, E. T., Irvine, P. J., Tingley, D. H., Xu, J., & Keith, D. W. (2021). Elicitation of US and Chinese expert judgments show consistent views on solar geoengineering. *Humanities and Social Sciences Communications*, *8*(1), 1–9. https://doi.org/10.1057/s41599-020-00694-6

Daoudy, M. (2021). Rethinking the Climate–Conflict Nexus: A Human–Environmental–Climate Security Approach. *Global Environmental Politics*, 1–22. https://doi.org/10.1162/glep_a_00609

Demaria, S., & Rigot, S. (2021). Corporate environmental reporting: Are French firms compliant with the Task Force on Climate Financial Disclosures' recommendations? *Business Strategy and the Environment*, *30*(1), 721–738. https://doi.org/10.1002/bse.2651

Denchak, M. (2019, July 16). Greenhouse Effect 101. *NRDC*. https://www.nrdc.org/stories/greenhouse-effect-101

Dennig, F., Budolfson, M. B., Fleurbaey, M., Siebert, A., & Socolow, R. H. (2015). Inequality, climate impacts on the future poor, and carbon prices. *Proceedings of the National Academy of Sciences*, 112(52), 15827–15832. https://doi.org/10.1073/pnas.1513967112

Dorsch, M. J., & Flachsland, C. (2017). A Polycentric Approach to Global Climate Governance. *Global Environmental Politics*, *17*(2), 45–64. https://doi.org/10.1162/GLEP_a_00400

Dow, K., Berkhout, F., Preston, B. L., Klein, R. J. T., Midgley, G., & Shaw, M. R. (2013). Limits to adaptation. *Nature Climate Change*, *3*(4), 305–307. https://doi.org/10.1038/nclimate1847

Driessen, P. P. J., & Rijswick, H. F. M. W. van. (2011). Normative aspects of climate adaptation policies. *Climate Law*, *2*(4), 559–581. https://doi.org/10.1163/CL-2011-051

Eskander, S. M. S. U., & Fankhauser, S. (2020). Reduction in greenhouse gas emissions from national climate legislation. *Nature Climate Change*, *10*(8), 750–756. https://doi.org/10.1038/s41558-020-0831-z

Evans, S. (2021, October 5). Analysis: Which countries are historically responsible for climate change? *Carbon Brief*. https://www.carbonbrief.org/analysis-which-countries-are-historically-responsible-for-climate-change

Felgenhauer, T., Horton, J., & Keith, D. (2022). Solar geoengineering research on the U.S. policy agenda: when might its time come? *Environmental Politics, 31*(3), 498–518. https://doi.org/10.1080/09644016.2021.1933763

Fisher, E. (2013). Climate Change Litigation, Obsession and Expertise: Reflecting on the Scholarly Response to Massachusetts v. EPA. *Law & Policy*, *35*(3), 236–260. https://doi.org/10.1111/lapo.12006

Fleurbaey, M., Ferranna, M., Budolfson, M., Dennig, F., Mintz-Woo, K., Socolow, R., Spears, D., & Zuber, S. (2019). The Social Cost of Carbon: Valuing Inequality, Risk, and Population for Climate Policy. *The Monist*, *102*(1), 84–109. https://doi.org/10.1093/monist/ony023

Fleurbaey, M., & Zuber, S. (2012). Climate Policies Deserve a Negative Discount Rate. *Chicago Journal of International Law*, 13(2), 565–596.

Frank, W., Bals, C., & Grimm, J. (2019). The Case of Huaraz: First Climate Lawsuit on Loss and Damage Against an Energy Company Before German Courts. In R. Mechler, L. M. Bouwer, T. Schinko, S. Surminski, & J. Linnerooth-Bayer (Eds.), *Loss and Damage from Climate Change: Concepts, Methods and Policy Options* (pp. 475–482). Springer International Publishing. https://doi.org/10.1007/978-3-319-72026-5_20

Friedlingstein, P., Allen, M., Canadell, J. G., Peters, G. P., & Seneviratne, S. I. (2019). Comment on "The global tree restoration potential". *Science*, *366*(6463). https://doi.org/10.1126/science.aay8060

Ganguly, G., Setzer, J., & Heyvaert, V. (2018). If at First You Don't Succeed: Suing Corporations for Climate Change. *Oxford Journal of Legal Studies*, *38*(4), 841–868. https://doi.org/10.1093/ojls/gqy029

Garschagen, M., Doshi, D., Moure, M., James, H., & Shekhar, H. (2021). The consideration of future risk trends in national adaptation planning: Conceptual gaps and empirical lessons. *Climate Risk Management*, *34*, 100357. https://doi.org/10.1016/j.crm.2021.100357

Gerrard, M. B., & Hester, T. (Eds.). (2018). *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal*. Cambridge University Press. https://doi.org/10.1017/9781316661864

Grieger, K. D., Felgenhauer, T., Renn, O., Wiener, J., & Borsuk, M. (2019). Emerging risk governance for stratospheric aerosol injection as a climate management technology. *Environment Systems and Decisions*, *39*(4), 371–382. https://doi.org/10.1007/s10669-019-09730-6

Gross, S. (2020). *Renewables, Land Use, and Local Opposition in the United States*. Brookings Institution. https://www.brookings.edu/wp-content/uploads/2020/01/FP_20200113_renewables_land_use_local_opposition_gross.pdf

Hagmann, D., Ho, E. H., & Loewenstein, G. (2019). Nudging out support for a carbon tax. *Nature Climate Change*, *9*(6), 484–489. https://doi.org/10.1038/s41558-019-0474-0

Haines, A., Kovats, R. S., Campbell-Lendrum, D., & Corvalan, C. (2006). Climate change and human health: Impacts, vulnerability and public health. *Public Health, 120*(7), 585–596. https://doi.org/10.1016/j.puhe.2006.01.002

Halstead, J. (2018). Stratospheric aerosol injection research and existential risk. *Futures*, *102*, 63–77. https://doi.org/10.1016/j.futures.2018.03.004

Halstead, J., & Ackva, J. (2020, October 6). Climate Change Executive Summary. *Founders Pledge*. https://founderspledge.com/stories/climate-change-executive-summary

Hart, D. M., & Noll, E. (2019). *Less Certain Than Death: Using Tax Incentives to Drive Clean Energy Innovation*. Information Technology and Innovation Foundation. https://itif.org/publications/2019/12/02/less-certain-death-using-tax-incentives-drive-clean-energy-innovation

Heede, R. (2014). Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. *Climatic Change*, *122*(1), 229–241. https://doi.org/10.1007/s10584-013-0986-y

Heffron, R. J. (2018). Energy law for decommissioning in the energy sector in the 21st century. *The Journal of World Energy Law & Business*, *11*(3), 189–195. https://doi.org/10.1093/jwelb/jwy013

Heinzerling, L., & Ackerman, F. (2007). Law and Economics for a Warming World. *Harvard Law & Policy Review*, *1*(2), 331–362.

Hester, T. (2018). Liability and Compensation. In M. B. Gerrard & T. Hester (Eds.), *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal* (pp. 224–268). Cambridge University Press. https://doi.org/10.1017/9781316661864.005

Hilson, C. (2020). Hitting the Target? Analysing the Use of Targets in Climate Law. *Journal of Environmental Law*, *32*(2), 195–220. https://doi.org/10.1093/jel/eqaa004

Hilton, B.. (2022, May 18). *Climate change: Is climate change the biggest threat facing humanity today?* 80,000 Hours. https://80000hours.org/problem-profiles/climate-change/

Hogan, J., & Haltinner, K. (2015). Floods, Invaders, and Parasites: Immigration Threat Narratives and Right-Wing Populism in the USA, UK and Australia. *Journal of Intercultural Studies*, *36*(5), 520–543. https://doi.org/10.1080/07256868.2015.1072907

Hsiang, S. M., Burke, M., & Miguel, E. (2013). Quantifying the Influence of Climate on Human Conflict. *Science*, *341*(6151). https://doi.org/10.1126/science.1235367

Humphreys, S. (Ed.). (2010). *Human Rights and Climate Change*. Cambridge University Press.

Huttunen, S., & Hildén, M. (2014). Framing the Controversial: Geoengineering in Academic Literature. *Science Communication*, *36*(1), 3–29. https://doi.org/10.1177/1075547013492435

IPCC. (2022a) *Climate Change 2022: Mitigation of ClimateChange. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

IPCC. (2022b) *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*

Ismer, R., & Neuhoff, K. (2007). Border tax adjustment: A feasible way to support stringent emission trading. *European Journal of Law and Economics*, *24*(2), 137–164. https://doi.org/10.1007/s10657-007-9032-8

Jehn, F. U., Schneider, M., Wang, J. R., Kemp, L., & Breuer, L. (2021). Betting on the best case: Higher end warming is underrepresented in research. *Environmental Research Letters*, *16*(8), 084036. https://doi.org/10.1088/1748-9326/ac13ef

Jones, N. (2018). Safeguarding Against Environmental Injustice: 1.5°C Scenarios, Negative Emissions, and Unintended Consequences. *Carbon & Climate Law Review*, *12*(1), 23–30. https://doi.org/10.21552/cclr/2018/1/6

Jordan, A. J., Huitema, D., Hildén, M., van Asselt, H., Rayner, T. J., Schoenefeld, J. J., Tosun, J., Forster, J., & Boasson, E. L. (2015). Emergence of polycentric climate governance and its future prospects. *Nature Climate Change*, *5*(11), 977–982. https://doi.org/10.1038/nclimate2725

Kareiva, P., & Carranza, V. (2018). Existential risk due to ecosystem collapse: Nature strikes back. *Futures*, *102*, 39–50. https://doi.org/10.1016/j.futures.2018.01.001

Kemp, L. (2021, October 26). Agents of Doom: Who is creating the apocalypse and why. *BBC Future*. https://www.bbc.com/future/article/20211014-agents-of-doom-who-is-hastening-the-apocalypse-and-why

Kennedy, D. (2013). Law and the Political Economy of the World. *Leiden Journal of International Law*, *26*(1), 7–48.

King, D., Schrag, D., Dadi, Z., Ye, Q., & Ghosh, A. (2015). *Climate Change: A Risk Assessment*. Cambridge Centre for Science and Policy. https://www.csap.cam.ac.uk/projects/climate-change-risk-assessment/

Kintisch, E. (2018). Technologies. In M. B. Gerrard & T. Hester (Eds.), *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal* (pp. 28–56). Cambridge University Press. https://doi.org/10.1017/9781316661864.002

Kotzé, L. J. (2020). Earth system law for the Anthropocene: Rethinking environmental law alongside the Earth system metaphor. *Transnational Legal Theory*, *11*(1–2), 75–104. https://doi.org/10.1080/20414005.2020.1776556

Kreienkamp, J., & Pegram, T. (2020). Governing Complexity: Design Principles for the Governance of Complex Global Catastrophic Risks. *International Studies Review*, *viaa074*. https://doi.org/10.1093/isr/viaa074

Kreuter, J. (2021). *Climate Engineering as an Instance of Politicization: Talking Tomorrow's Technology—Framing Political Choice?* Springer.

Kuhlemann, K. (2018). Complexity, creeping normalcy and conceit: Sexy and unsexy catastrophic risks. *Foresight*, *21*(1), 35–52. https://doi.org/10.1108/FS-05-2018-0047

Kysar, D. A. (2011). What Climate Change Can Do about Tort Law. *Environmental Law*, *41*(1), 1–72.

L. Perch-Nielsen, S., B. Bättig, M., & Imboden, D. (2008). Exploring the link between climate change and migration. *Climatic Change*, *91*(3), 375. https://doi.org/10.1007/s10584-008-9416-y

Larkin, A., Kuriakose, J., Sharmina, M., & Anderson, K. (2018). What if negative emission technologies fail at scale? Implications of the Paris Agreement for big emitting nations. *Climate Policy*, *18*(6), 690–714. https://doi.org/10.1080/14693062.2017.1346498

Laudari, H. K., Aryal, K., Bhusal, S., & Maraseni, T. (2021). What lessons do the first Nationally Determined Contribution (NDC) formulation process and implementation outcome provide to the enhanced/updated NDC? A reality check from Nepal. *Science of The Total Environment*, *759*, 143509. https://doi.org/10.1016/j.scitotenv.2020.143509

Legesse, B. A., Jefferson-Moore, K., & Thomas, T. (2018). Impacts of land tenure and property rights on reforestation intervention in Ethiopia. *Land Use Policy*, *70*, 494–499. https://doi.org/10.1016/j.landusepol.2017.11.018

Lehner, M., Mont, O., & Heiskanen, E. (2016). Nudging – A promising tool for sustainable consumption behaviour? *Journal of Cleaner Production*, *134*, 166–177. https://doi.org/10.1016/j.jclepro.2015.11.086

Lewis, S. C., Perkins-Kirkpatrick, S. E., Althor, G., King, A. D., & Kemp, L. (2019). Assessing Contributions of Major Emitters' Paris-Era Decisions to Future Temperature Extremes. *Geophysical Research Letters*, *46*(7), 3936–3943. https://doi.org/10.1029/2018GL081608

Lin, A. C. (2018). US Law. In M. B. Gerrard & T. Hester (Eds.), *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal* (pp. 154–223). Cambridge University Press. https://doi.org/10.1017/9781316661864.004

Liu, H.-Y., Lauta, K. C., & Maas, M. M. (2018). Governing Boring Apocalypses: A new typology of existential vulnerabilities and exposures for existential risk research. *Futures*, *102*, 6–19. https://doi.org/10.1016/j.futures.2018.04.009

Lynas, M. (2020). *Our Final Warning: Six Degrees of Climate Emergency*. HarperCollins UK.

Lyster, R. (2016). *Climate Justice and Disaster Law*. Cambridge University Press. https://doi.org/10.1017/CBO9781316227534

Lyster, R., & Verchick, R. (2018). *Research Handbook on Climate Disaster Law*. Edward Elgar Publishing.

Malm, A. (2021). *How to Blow Up a Pipeline*. Verso Books.

Markkanen, S., & Anger-Kraavi, A. (2019). Social impacts of climate change mitigation policies and their implications for inequality. *Climate Policy*, *19*(7), 827–844. https://doi.org/10.1080/14693062.2019.1596873

Markusson, N., Ginn, F., Ghaleigh, N. S., & Scott, V. (2014). 'In case of emergency press here': Framing geoengineering as a response to dangerous climate change. *WIREs Climate Change*, *5*(2), 281–290. https://doi.org/10.1002/wcc.263

Martinez, E., & Winter, C. (2021). *Protecting future generations: A global survey of legal academics*[LPP Working Paper Series N° 1-2021]. Legal Priorities Project. https://www.legalpriorities.org/documents/protecting-future-generations.pdf

Mayer, B. (2018). The Critical Functions of Scholarship in Climate Law. *Climate Law*, *8*(3–4), 151–160. https://doi.org/10.1163/18786561-00803002

Mayer, B. (2019). Interpreting States' general obligations on climate change mitigation: A methodological review. *Review of European, Comparative & International Environmental Law*, *28*(2), 107–121. https://doi.org/10.1111/reel.12285

Mayer, B. (2021). Climate Change Mitigation as an Obligation Under Human Rights Treaties? *American Journal of International Law*, 115(3), 409–451. https://doi.org/10.1017/ajil.2021.9

McAdam, J. (2012). *Climate Change, Forced Migration, and International Law*. OUP Oxford.

McDonald, J. (2011). The role of law in adapting to climate change. *WIREs Climate Change*, *2*(2), 283–295. https://doi.org/10.1002/wcc.96

Mehryar, S., & Surminski, S. (2021). National laws for enhancing flood resilience in the context of climate change: Potential and shortcomings. *Climate Policy*, *21*(2), 133–151. https://doi.org/10.1080/14693062.2020.1808439

Meinshausen, M., Lewis, J., McGlade, C., Gütschow, J., Nicholls, Z., Burdon, R., Cozzi, L., & Hackmann, B. (2022). Realization of Paris Agreement pledges may limit warming just below 2 °C. *Nature, 604*(7905), 304–309. https://doi.org/10.1038/s41586-022-04553-z

Morton, O. (2015). *The Planet Remade: How Geoengineering Could Change the World*. Princeton University Press.

Narassimhan, E., Gallagher, K. S., Koester, S., & Alejo, J. R. (2018). Carbon pricing in practice: A review of existing emissions trading systems. *Climate Policy*, *18*(8), 967–991. https://doi.org/10.1080/14693062.2018.1467827

Nave, L. E., Walters, B. F., Hofmeister, K. L., Perry, C. H., Mishra, U., Domke, G. M., & Swanston, C. W. (2019). The role of reforestation in carbon sequestration. *New Forests*, *50*(1), 115–137. https://doi.org/10.1007/s11056-018-9655-3

Ng, Y.-K. (2016). The Importance of Global Extinction in Climate Change Policy. *Global Policy*, *7*(3), 315–322. https://doi.org/10.1111/1758-5899.12318

Nielsen, K. S., Nicholas, K. A., Creutzig, F., Dietz, T., & Stern, P. C. (2021). The role of high-socioeconomic-status people in locking in or rapidly reducing energy-driven greenhouse gas emissions. *Nature Energy, 6*(11), 1011–1016. https://doi.org/10.1038/s41560-021-00900-y

Nordås, R., & Gleditsch, N. P. (2015). Climate Change and Conflict. In S. Hartard & W. Liebert (Eds.), *Competition and Conflicts on Resource Use* (pp. 21–38). Springer International Publishing. https://doi.org/10.1007/978-3-319-10954-1_3

Nordhaus, W. D. (2011). The Economics of Tail Events with an Application to Climate Change. *Review of Environmental Economics and Policy*, *5*(2), 240–257. https://doi.org/10.1093/reep/rer004

Okereke, C., & Coventry, P. (2016). Climate justice and the international regime: Before, during, and after Paris. *WIREs Climate Change*, *7*(6), 834–851. https://doi.org/10.1002/wcc.419

Oomen, J. (2021). *Imagining Climate Engineering: Dreaming of the Designer Climate*. Routledge. https://doi.org/10.4324/9781003043553

Ord, T. (2020). *The Precipice: Existential Risk and the Future of Humanity* Hachette Books.

Osaka, S. (2021, April 8). Why a landmark experiment into dimming the sun got canceled. *Grist*. https://grist.org/science/who-gets-to-decide-if-we-study-solar-geoengineering-after-the-scopex-project-canceled/

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, *20*(4), 550–557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Parson, E. A., & Keith, D. W. (2013). End the Deadlock on Governance of Geoengineering Research. *Science*, *339*(6125), 1278–1279. https://doi.org/10.1126/science.1232527

Parson, E. A., & Reynolds, J. L. (2021). Solar geoengineering: Scenarios of future governance challenges. *Futures*, *133*, 102806. https://doi.org/10.1016/j.futures.2021.102806

Patel, J. R. (2017). Deep Seeded Problems: A Look at Seed Bank Regulations. *Seattle Journal of Environmental Law*, *7*, 132–155.

Peel, J., & Osofsky, H. M. (2018). A Rights Turn in Climate Change Litigation? *Transnational Environmental Law*, *7*(1), 37–67. https://doi.org/10.1017/S2047102517000292

Pelling, M., & Garschagen, M. (2019). Put equity first in climate adaptation. *Nature*, 569(7756), 327–329. https://doi.org/10.1038/d41586-019-01497-9

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., Bontzorlos, V., Clough, D., Bezák, P., Bonn, A., Hansjürgens, B., Lomba, A., Möckel, S., Passoni, G., Schleyer, C., Schmidt, J., & Lakner, S. (2019). A greener path for the EU Common Agricultural Policy. Science. https://doi.org/10.1126/science.aax3146

Pickering, J., McGee, J. S., Karlsson-Vinkhuyzen, S. I., & Wenta, J. (2019). Global Climate Governance Between Hard and Soft Law: Can the Paris Agreement's 'Crème Brûlée'

Approach Enhance Ecological Reflexivity? *Journal of Environmental Law*, *31*(1), 1–28. https://doi.org/10.1093/jel/eqy018

Pindyck, R. S. (2017). The Use and Misuse of Models for Climate Policy. *Review of Environmental Economics and Policy*, *11*(1), 100–114. https://doi.org/10.1093/reep/rew012

Piper, K. (2019, June 13). Is climate change an 'existential threat'—Or just a catastrophic one? *Vox*. https://www.vox.com/future-perfect/2019/6/13/18660548/climate-change-human-civilization-existential-risk

Rajamani, L. (2012). The changing fortunes of differential treatment in the evolution of international environmental law. *International Affairs*, *88*(3), 605–623. https://doi.org/10.1111/j.1468-2346.2012.01091.x

Rajamani, L., & Brunnée, J. (2017). The Legality of Downgrading Nationally Determined Contributions under the Paris Agreement: Lessons from the US Disengagement. *Journal of Environmental Law*, *29*(3), 537–551. https://doi.org/10.1093/jel/eqx024

Rajamani, L., Jeffery, L., Höhne, N., Hans, F., Glass, A., Ganti, G., & Geiges, A. (2021). National 'fair shares' in reducing greenhouse gas emissions within the principled framework of international environmental law. *Climate Policy*, *21*(8), 983–1004. https://doi.org/10.1080/14693062.2021.1970504

Rao, N. D., & Min, J. (2018). Less global inequality can improve climate outcomes. *WIREs Climate Change*, *9*(2), e513. https://doi.org/10.1002/wcc.513

Rayner, S., Heyward, C., Kruger, T., Pidgeon, N., Redgwell, C., & Savulescu, J. (2013). The Oxford Principles. *Climatic Change*, *121*(3), 499–512. https://doi.org/10.1007/s10584-012-0675-2

Reynolds, J. L. (2014). The International Regulation of Climate Engineering: Lessons from Nuclear Power. *Journal of Environmental Law*, *26*(2), 269–289. https://doi.org/10.1093/jel/equ006

Reynolds, J. L. (2019). *The Governance of Solar Geoengineering:Managing Climate Change in the Anthropocene*. Cambridge University Press.

Reynolds, J. L. (2021). Linking solar geoengineering and emissions reductions: Strategically resolving an international climate change policy dilemma. *Climate Policy*, *0*(0), 1–16. https://doi.org/10.1080/14693062.2021.1993125

Reynolds, J. L., & Parson, E. A. (2020). Nonstate governance of solar geoengineering research. *Climatic Change*, *160*(2), 323–342. https://doi.org/10.1007/s10584-020-02702-9

Richards, C. E., Lupton, R. C., & Allwood, J. M. (2021). Re-framing the threat of global warming: An empirical causal loop diagram of climate change, food insecurity and societal collapse. *Climatic Change*, *164*(3), 49. https://doi.org/10.1007/s10584-021-02957-w

Richardson, B. J. (2012). *Local Climate Change Law: Environmental Regulation in Cities and Other Localities*. Edward Elgar Publishing.

Rimmer, M. (2011). *Intellectual Property and Climate Change: Inventing Clean Technologies*. Edward Elgar Publishing.

Rimmer, M. (2021). Carbon capture and storage: Intellectual property, innovation policy, and climate change. In H. K. de Medeiros Costa & C. Arlota (Eds.), *Carbon Capture and Storage in International Energy Policy and Law* (pp. 181–203). Elsevier. https://doi.org/10.1016/B978-0-323-85250-0.00012-8

Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K., & Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature*, *534*(7609), 631–639. https://doi.org/10.1038/nature18307

Rowell, A. & Bilz, K. (2021). *The Psychology of EnvironmentalLaw*. New York University Press.

Rowell, A. (2020). Regulating Best Case Scenarios. *Environmental Law 50*(4), 1105–1172.

Ruhl, J. B., & Salzman, J. (2012). Climate change Meets the Law of the Horse. *Duke Law Journal*, *62*(5), 975–1028.

Ryngaert, C. (2017). Climate Change Mitigation Techniques and International Law: Assessing the Externalities of Reforestation and Geoengineering. *Ratio Juris*, *30*(3), 273–289. https://doi.org/10.1111/raju.12154

Sainati, T., Locatelli, G., & Smith, N. (2019). Project financing in nuclear new build, why not? The legal and regulatory barriers. *Energy Policy*, *129*, 111–119. https://doi.org/10.1016/j.enpol.2019.01.068

Sandberg, A. (2019, May 29). Will climate change cause humans to go extinct? *The Conversation*. http://theconversation.com/will-climate-change-cause-humans-to-go-extinct-117691

Saurer, J., & Monast, J. (2021). The Law of Energy Transition in Federal Systems. *Transnational Environmental Law*, *10*(2), 205–210. https://doi.org/10.1017/S2047102521000194

Schmidt, A. T., & Juijn, D. (2021). *Economic inequality and the long-term future* (No. 4-2021; GPI Working Paper). Global Priorities Institute. https://globalprioritiesinstitute.org/economic-inequality-and-the-long-term-future-andreas-t-schmidt-university-of-groningen-and-daan-juijn-ce-delft/

Scott, J., & Rajamani, L. (2012). EU Climate Change Unilateralism. *European Journal of International Law*, *23*(2), 469–494. https://doi.org/10.1093/ejil/chs020

Sebo, J. (2021). Animals and Climate Change. In M. Budolfson, T. McPherson, & D. Plunkett (Eds.), *Philosophy and Climate Change*. Oxford University Press. https://doi.org/10.1093/oso/9780198796282.003.0003

Setzer, J., & Vanhala, L. C. (2019). Climate change litigation: A review of research on courts and litigants in climate governance. *WIREs Climate Change*, *10*(3), e580. https://doi.org/10.1002/wcc.580

Sherwood, S. C., & Huber, M. (2010). An adaptability limit to climate change due to heat stress. *Proceedings of the National Academy of Sciences*, *107*(21), 9552–9555.

Sherwood, S. C., Webb, M. J., Annan, J. D., Armour, K. C., Forster, P. M., Hargreaves, J. C., Hegerl, G., Klein, S. A., Marvel, K. D., Rohling, E. J., Watanabe, M., Andrews, T., Braconnot, P., Bretherton, C. S., Foster, G. L., Hausfather, Z., Heydt, A. S. von der, Knutti, R., Mauritsen, T., … Zelinka, M. D. (2020). An Assessment of Earth's Climate Sensitivity Using Multiple Lines of Evidence. *Reviews of Geophysics, 58*(4), e2019RG000678. https://doi.org/10.1029/2019RG000678

Stephens, J. C., Kashwan, P., McLaren, D., & Surprise, K. (2021). The risks of solar geoengineering research. *Science*. https://doi.org/10.1126/science.abj3679

Stuart-Smith, R. F., Otto, F. E. L., Saad, A. I., Lisi, G., Minnerop, P., Lauta, K. C., van Zwieten, K., & Wetzer, T. (2021). Filling the evidentiary gap in climate litigation. *Nature Climate Change*, 1–5. https://doi.org/10.1038/s41558-021-01086-7

Stucki, S., Futhazar, G., Sparks, T., Tuchtfeld, E., & Foehr, H. (2021, September 7). World Lawyers' Pledge on Climate Action: An Urgent Call for Climate Mainstreaming. *EJIL: Talk!* https://www.ejiltalk.org/world-lawyers-pledge-on-climate-action-an-urgent-call-for-climate-mainstreaming/

Suiseeya, K. R. M. (2017). Contesting Justice in Global Forest Governance: The Promises and Pitfalls of REDD+. *Conservation and Society*, *15*(2), 189–200.

Sunstein, C. R. (2002). Probability Neglect: Emotions, Worst Cases, and Law. *The Yale Law Journal*, *112*(1), 61–107. https://doi.org/10.2307/1562234

Sunstein, C. R. (2009). *Worst Case Scenarios*. Harvard University Press.

Sunstein, C. R. (2021). *Averting Catastrophe: Decision Theory for COVID-19, Climate Change, and Potential Disasters of All Kinds* New York University Press.

Sunstein, C. R. (2022). Arbitrariness Review and Climate Change. University of Pennsylvania Law Review, 170, 991–1047.

Taconet, N., Méjean, A., & Guivarch, C. (2020). Influence of climate change impacts and mitigation costs on inequality between countries. *Climatic Change*, 160(1), 15–34. https://doi.org/10.1007/s10584-019-02637-w

Timperley, J. (2020, June 19). Who is really to blame for climate change? *BBC Futures*. https://www.bbc.com/future/article/20200618-climate-change-who-is-to-blame-and-why-does-it-matter

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: A review. *Global Change Biology*, *20*(11), 3313–3328. https://doi.org/10.1111/gcb.12581

Tucker, W. C. (2012). Deceitful Tongues: Is Climate Change Denial a Crime. *Ecology Law Quarterly*, *39*(3), 831–894.

Vallejo, M. C., Burbano, R., Falconí, F., & Larrea, C. (2015). Leaving oil underground in Ecuador: The Yasuní-ITT initiative from a multi-criteria perspective. *Ecological Economics*, *109*, 175–185. https://doi.org/10.1016/j.ecolecon.2014.11.013

Veldman, J. W., Aleman, J. C., Alvarado, S. T., Anderson, T. M., Archibald, S., Bond, W. J., Boutton, T. W., Buchmann, N., Buisson, E., Canadell, J. G., Dechoum, M. de S., Diaz-Toribio, M. H., Durigan, G., Ewel, J. J., Fernandes, G. W., Fidelis, A., Fleischman, F., Good, S. P., Griffith, D. M., … Zaloumis, N. P. (2019). Comment on "The global tree restoration potential". *Science*, *366*(6463). https://doi.org/10.1126/science.aay7976

Vernooy, R., Sthapit, B., Otieno, G., Shrestha, P., & Gupta, A. (2017). The roles of community seed banks in climate change adaption. *Development in Practice*, *27*(3), 316–327. https://doi.org/10.1080/09614524.2017.1294653

Vihma, A. (2013). Analyzing Soft Law and Hard Law in Climate Change. In E. J. Hollo, K. Kulovesi, & M. Mehling (Eds.), *Climate Change and the Law* (pp. 143–164). Springer Netherlands. https://doi.org/10.1007/978-94-007-5440-9_7

Villoria-Sáez, P., Tam, V. W. Y., Río Merino, M. del, Viñas Arrebola, C., & Wang, X. (2016). Effectiveness of greenhouse-gas Emission Trading Schemes implementation: A review on legislations. *Journal of Cleaner Production*, *127*, 49–58. https://doi.org/10.1016/j.jclepro.2016.03.148

Wallace, P. E. (2009). Climate Change, Corporate Strategy, and Corporate Law Duties Corporate Governance and Climate Change. *Wake Forest Law Review*, *44*(3), 757–776.

Wagner, G., Anthoff, D., Cropper, M., Dietz, S., Gillingham, K. T., Groom, B., Kelleher, J. P., Moore, F. C., & Stock, J. H. (2021). Eight priorities for calculating the social cost of carbon. *Nature, 590*(7847), 548–550. https://doi.org/10.1038/d41586-021-00441-0.

Wegener, L. (2020). Can the Paris Agreement Help Climate Change Litigation and Vice Versa? *Transnational Environmental Law*, *9*(1), 17–36. https://doi.org/10.1017/S2047102519000396

Weinberger, J., Drozdowska, A., & Pinkerton, B. (2020, January 22). How Germany helped make renewable energy cheap for the rest of the world. *Vox*. https://www.vox.com/2020/1/22/21028914/germany-green-new-deal-solar-power

Weitzmann, M. L. (1998). Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate. *Journal of Environmental Economicsand Management, 36*(3), 201–208. https://doi.org/10.1006/jeem.1998.1052

Weitzman, M. L. (2011). Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change. *Review of Environmental Economics and Policy 5*(2), 275–292. https://doi.org/10.1093/reep/rer006

Wenta, J., McDonald, J., & McGee, J. S. (2019). Enhancing Resilience and Justice in Climate Adaptation Laws. *Transnational Environmental Law*, *8*(1), 89–118. https://doi.org/10.1017/S2047102518000286

Wewerinke-Singh, M. (2019). *State Responsibility, Climate Change and Human Rights under International Law*. Bloomsbury Publishing.

Wiener, J. B. (2016). The Tragedy of the Uncommons: On the Politics of Apocalypse.*Global Policy, 7*(1), 67–80. https://doi.org/10.1111/1758-5899.12319

Wildermuth, A. J. (2011). The Next Step: The Integration of Energy Law and Environmental Law. *Utah Environmental Law Review*, *31*, 369.

Williamson, P., & Bodle, R. (2016). *Update on climate geoengineering in relation to the Convention on Biological Diversity: Potential impacts and regulatory framework*. CBD Technical Series No. 84. https://www.cbd.int/doc/publications/cbd-ts-84-en.pdf

Work, C. (2019). Climate change and conflict: Global insecurity and the road less traveled. *Geoforum*, *102*, 222–225. https://doi.org/10.1016/j.geoforum.2018.11.004

Wunderling, N., Donges, J. F., Kurths, J., & Winkelmann, R. (2021). Interacting tipping elements increase risk of climate domino effects under global warming. *Earth System Dynamics*, *12*(2), 601–619. https://doi.org/10.5194/esd-12-601-2021

Zürn, M., & Schäfer, S. (2013). The Paradox of Climate Engineering. *Global Policy*, *4*(3), 266–277. https://doi.org/10.1111/gpol.12004