Techno-fixing non-compliance - Geoengineering, ideal theory and residual responsibility

Sand, M.; Hofbauer, B.; Alleblas, J.

DOI
10.1016/j.techsoc.2023.102236

Publication date
2023

Document Version
Final published version

Published in
Technology in Society

Technology in Society 73 (2023) 102236

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Techno-fixing non-compliance - Geoengineering, ideal theory and residual responsibility

Martin Sand *, Benjamin P. Hofbauer, Joost Alleblas

TU Delft, Department of Values, Technology and Innovation, Jaffalaan 5, 2628 BX, Delft, the Netherlands

ARTICLE INFO

Keywords:
Geoengineering
Responsibility
Techno-fix
Ideal theory
Non-compliance
Climate change

ABSTRACT

After years of missing the agreed upon goals for carbon reduction, we might conclude that global climate policies set infeasible standards to halt climate change. The widespread non-compliance of many signees with frameworks such as the Paris Agreement indicates that these frameworks were too optimistic regarding the signees' motivation to act. One of the suggested ways out of this impasse, is geoengineering, which is seen as a "techno-fix" of the non-compliance problem, relieving signees and other actors of some, or most, of their mitigation duties. This paper scrutinizes different approaches towards climate mitigation that focus on behavioral change or on technological solutions. We argue that these different approaches do not originate from categorically different theories of climate justice. Indeed, seemingly realistic and seemingly idealistic proposals do not disagree on the substance of climate justice, but about what is to be considered feasible. Furthermore, by applying this dialectic lens on ideal vs. non-ideal theorizing in the context of climate justice, we show that (backward-looking) residual responsibility is an overlooked aspect of geoengineering as a (forward-looking) non-ideal approach to achieve climate justice. We will outline three possible consequences of this moral residue: 1) Residual responsibility can provide grounds to demand compensation, 2) it can constitute other forward-looking responsibilities (e.g., the maintenance of geoengineering technologies) and 3) it provides a reason to employ other techno-fixes equal in effectiveness and risks that do not sidestep the problem of non-compliance.

1. Introduction

Almost all current discussions about climate change and the effectiveness of climate policies conclude that current mitigation efforts are insufficient [1]. Nation states, corporations, and citizens do not sufficiently comply with duties conceived as essential in halting climate change. Some of these duties form part of international agreements, others follow from assumptions about the rationality and reasonability of individual actors. Given this widespread non-compliance, one could assume that the goals set in frameworks such as the 2015 Paris Agreement (PA) and the Kyoto Protocol (KP) function as unfeasible aspirations rather than realistic ambitions. This assumption of infeasibility, furthermore, might lead to a consideration of more realistic forms of climate mitigation that suit a world in which non-compliance is prevalent.

Various approaches to deal with non-compliance are discussed in the literature; first, reducing climate change targets in policy frameworks, to make their demands more realistic and, thus, easier to achieve, also known as "target modifications" [2]; p. 26 f.) Second, suggestions to change economic incentives so that freeriding and non-compliance stop being economically beneficial [3]. A third strategy to counteract non-compliance with the demands of mitigation policies, themselves based on standards set in (inter)national agreements, is geoengineering [4]. Geoengineering comprises a variety of different technologies that

* Corresponding author.
E-mail address: m.sand@tudelft.nl (M. Sand).

https://doi.org/10.1016/j.techsoc.2023.102236
Received 20 October 2022; Received in revised form 11 March 2023; Accepted 20 March 2023
Available online 22 March 2023

aim to mitigate or even halt climate change [5].[1]

Currently, most if not all scholars understand geoengineering as an additional measure in the face of increasingly catastrophic climate change. Intentionally cooling the global climate by way of increasing the earth's reflection levels (i.e. Solar Radiation Modification (SRM)) or reducing atmospheric carbon, does not substitute adaptation and mitigation. Rather, these techniques serve as an additional means to reduce some of the most harmful climate impacts, such as rapid sea level rise, or the exponential increase in catastrophic weather events (e.g. droughts or floods). As such, these interventions could provide a lifeline to some irresponsible practices, such as the continuous use and construction of coal-fired power plants, and, thus, inhibit the necessary decarbonization of the energy system. Therefore, some people may perceive geoengineering as an easy way out: Instead of doing the hard work of changing the energy system, the (mere potential) of geoengineering technologies could be used as a reason against thorough climate action. This is what scholars critical of geoengineering, and SRM in particular, frame as "moral hazard" or "mitigation deterrence" [6–8].[2]

Thus, geoengineering can and has been framed as a "techno-fix" for the problem of non-compliance with climate mitigation duties. In short, rather than motivating people to follow up on their duties and responsibilities, geoengineering technologies discharge relevant agents of many, if not all, of their duties and responsibilities. The general idea of techno-fixing various moral, political or social problems has been criticized in a variety of contexts. For one, they are criticized as being part of the initial problem rather than an innovative way out of it [9]. Second, techno-fixes inevitably create new and bigger problems and distract from discussions about non-technological solutions [9–11]. Third, technofixes impact our perceived moral agency, as technologies are designed to behave responsibly in our steads [6]. These criticisms raise the question whether techno-fixing non-compliance through geoengineering is morally permissible. This permissibility can be qualified by assessing geoengineering's risks and benefits (see, for example, [12, 13].[3]

In the present article, we will focus on another, neglected aspect of the proposal to fix non-compliance with geoengineering – residual responsibility. Firstly, we will show that non-compliance is not a problem of a particular type or category of theories of climate justice. Few, if any, climate justice theories propose climate justice principles through deductive reasoning, starting at a platonic ideal of justice. Many climate justice theories (and subsequent policy frameworks) might have been unrealistic in their assumptions about human motivation and compliance, but that does not automatically place them squarely in the category of ideal theories. Further, we will argue that geoengineering framed as a techno-fix bypasses the fulfillment of relevant moral obligations, without abolishing them. This gives rise to a collective backward-looking responsibility, which we will examine in much detail. Importantly, this bypassing stands even if geoengineering is merely an additional means to reduce climate harms.

The present article is organized as follows: Section 2 elaborates on different forms of techno-fixes to better grasp the techno-moral dimensions of geoengineering. Sections 3 and 4 discuss different theoretical assumptions about climate justice in relation to policy frameworks such as PA and KP. These sections also show how the notion of feasibility oftentimes forms the nucleus of contention rather than an alleged categorical difference between types of climate justice theories. We then build up on the previously introduced taxonomy in sections 5 and 6: Referencing insights from the debate about ideal vs. non-ideal theories, we argue that geoengineering as a response to non-compliance gives rise to residual responsibilities, even if the problem of climate change could be made more easily manageable through geoengineering. These responsibilities are an overlooked moral dimension in the debate. From there, we consider the weight and implications of this dimension. Residual responsibilities might provide grounds 1) for a liability to compensate, 2) to prefer other types of techno-fixes of the compliance problem, or 3) for a forward-looking responsibility to maintain geoengineering technologies, policies, and practices. In our concluding remarks in section 7, we summarize the results of the present paper and suggest that ideal theory, while not in need of defense against realist charges in the context of climate change justice, serves as a reminder that geoengineering does not relieve us of the responsibility to comply with the duties and responsibilities that flow from (inter)national agreements and well-justified moral duties.

2. A taxonomy of techno-fixes

For the purpose of the present paper, we shall distinguish various types of techno-fixes to see where geoengineering fits in. The term "techno-fix" is used to describe a variety of technologies employed to respond to intractable societal problems, which have proven to be difficult or insoluble through political, legal and cultural reform [14]. These technologies can be distinguished based on their relation to human, moral agency (see also [6],[4]: First, there are techno-fixes that widen the impact of human action, while the moral quality of the action remains largely or entirely unaltered (think of apps that help you trace the emission cycle of products that you are interested in purchasing). One might consider those techno-fixes as *enhancers*. Enhancers do not tackle the non-compliance problem: They merely increase the impact of those agents who already were compliant and already directed their motivation towards the right ends. This might even make these actors do more than their fair share, so that other agents need not comply or do less than their fair share.

Second, there are techno-fixes that support agents making the right decisions by reminding them of their responsibilities or lowering the threshold of taking responsibility. Consider a (digital) calendar that reminds you of a friend's birthday, which you would have otherwise forgotten. The technology does not improve your action's effectiveness and neither does it alter your motivational setup. You already had the intent to congratulate and, thus, to comply with your cordial duties. Only, you needed some assistance to not forget about it. Nudges, too, might be put into this category. While, in contrast to enhancers, they do induce changes in the motivational setup of the agent, they do not entirely undermine their responsibility-taking either. They do not cause a motivational change because of coercion or force. As Mark Alfano and Philip Robichaud write:

[1] The two most prominent geoengineering strategies are Solar Radiation Management (SRM), which considers the infusion of particles into the atmosphere to reduce solar radiation absorption on earth's surface [47], and Carbon Dioxide Reduction (CDR), which considers diverse methods to increase the efficiency of carbon dioxide cycle in the earth [48]. SRM is gaining traction within the climate science and justice debate, as it is argued by some as a potential alleviation for the harms and risks of unabated climate change [47,49, 12]. Other scholars however warn of researching SRM, arguing that it represents a hubristic techno-fix to the complex societal problems which climate change brings [50]. Since the risks associated with these different technologies might diverge, risk-based moral arguments will not equally apply to those interventions. Importantly, the most recent IPCC report considers certain forms of CDR (i.e. negative emissions) as central to achieving any net-zero targets (see Ref. [51]. Nonetheless, the core issue of compliance, techno-fix, and residual responsibilities raised in this paper are relevant to either approach.

[2] cf [52]. give an important critical response to this charge.

[3] [53] have clearly identified the perils of these approaches.

[4] The presented taxonomy is in various ways incomplete and could be further expanded or narrowed. Nonetheless, this classification helps to locate geoengineering across a spectrum of technologies that differ in their way of responding to non-compliance. This also suffices to show that in some regards – e.g. of residual responsibility – geoengineering is not without alternatives. Neither of the first two categories face the argument we expose in the present paper.

> "We contend that many instances of nudging tacitly assign responsibility to nudgees for actions, values, and relationships for which they might not otherwise have taken responsibility. In so doing, such nudges do not bypass the agent's reasoning or values; instead, they engage the agent's reasoning and values by prompting them (if only unconsciously) to **accept responsibility**. To the extent that nudgees tacitly or explicitly accept such assignments, **they thereby become responsible** [own emphasis] for upholding norms that would otherwise have fallen under the purview of other actors, such as the state or those with more political, economic, or epistemic power." [15][5]

However, Alfano and Robichaud also argue that the social structure in which nudges function can create significant problems related to the possible abuse of paternalistic power that choice architects exert. Agents accepting the nudges, accept the norms and values of those with more political, economic, or epistemic power. Nudges might also reduce support for more drastic policies [16]. The dominance of nudges, furthermore, has overshadowed alternative forms of behavioral economics in public policy [17]. These features might considerably affect the coordination and cooperation necessary for minimizing non-compliance with climate change duties. In other words, although nudges might induce people to act more in concordance with their perceived goals, aligning their behavior with their intentions, nudges are not empowering [18].[6]

Thirdly and lastly, geoengineering as a techno-fix, unlike enhancers or nudging technologies, does not actually support compliance with climate change duties, or behavioral intentions. It does not affect in a direct way the motivational setup of moral agents, nor does it increase the impact of mitigating actions of those, who are willing to comply. While the technology is, for now, considered mainly as an additional measure, the potential of it being politically framed as a justification to continue business-as-usual emissions, lies at the heart of geoengineering criticism, and motivate calls to ban SRM research [19,20].

In a similar vein, Fragnière and Gardiner point out that framing of SRM research as a "Plan B″ in case mitigation and adaption turn out to be insufficient already puts humanity on a dangerous path to the deployment of such technology [21]. The "Plan B″-framing portrays geoengineering as a solution that supposedly relieves everyone from climate mitigation duties and accompanied burdens, or at the very least gives a reasonable, if not perfectly just, alternative. From this perspective, very much unlike nudging and enhancing, geoengineering constitutes an opportunity to offload responsibilities and, thereby, sidestep the problem of non-compliance. This aspect of geoengineering as a techno-fix for non-compliance has implications that have been widely neglected, as we will show in more detail in sections 5 and 6.

3. Climate justice and realist policies

In this section, we do not commit either to realism or idealism regarding climate justice. Instead, by mapping the arguments in defense of realistic or idealistic approaches to climate justice and locating geoengineering in this debate, we show that a) the difference between ideal and non-ideal theorizing, even if almost never explicitly rejected or embraced, is a useful angle to carve out the consequences in terms of residual responsibility when deploying geoengineering as a response to climate change; b) one often finds implicit idealizations in seemingly realistic reasonings about how to approach non-compliance and, more generally, c) that, while more and more often employed in this context, the intricate philosophical distinction between ideal and non-ideal theorizing is hardly ever clear cut in the debate about climate justice. The notion of feasibility forms the nucleus of contention rather than a categorical difference between these types of climate justice theories.

Both the topics of geoengineering and the place of moral ideals in political philosophy have developed their own bourgeoning debates. They are also more and more often brought together. Current commentators agree that most nations and most individuals do not contribute enough to mitigate the threat of climate change. This non-compliance with climate mitigation duties seemingly provides good grounds to dismiss, as too idealistic, the reasoning from which these duties stem. Ideal theories of climate justice, in this argument, set standards for (climate) justice regardless of real-world constraints, regardless, thus, of the feasibility of these standards. These theories are considered aspirational, rather than action-guiding in real-world contexts. Hence, the non-compliance with PA and KP show that these proposals, are built on ideas of what ought to be the case, regardless of the abilities of actors. In this sense, these proposals could be seen as products of ideal theorizing about global climate justice.

In his The *Idea of Justice* [22], Amartya Sen holds that accounts of ideal justice (in his terminology, instances of transcendental institutionalism) have two distinct features:

> "First, it concentrates its attention on what it identifies as perfect justice, rather than on relative comparisons of justice and injustice. It tries only to identify social characteristics that cannot be transcended in terms of justice, and its focus is thus not on comparing feasible societies, all of which may fall short of the ideals of perfection. The inquiry is aimed at identifying the nature of 'the just', rather than finding some criteria for an alternative being 'less unjust' than another. Second, in searching for perfection, transcendental institutionalism concentrates primarily on getting the institutions right, and it is not directly focused on the actual societies that would ultimately emerge." [22]; p. 5 f.)[7]

For instance, following such transcendental reasoning, it might seem perfectly just, if those agents who emitted historically most greenhouse gases should also voluntarily carry most of the economic burdens of climate change mitigation. This, however, might be infeasible in various ways: It could be impossible to determine the degrees to which certain countries emitted previously [23], and it seems infeasible that they would voluntarily do so (since they are currently less affected by the consequences of climate change and, thus, lack a strong incentive). In this way, a resulting lack of compliance shows the infeasibility of the proposed idea of justice. Hence, one might reject this type of reasoning as idealistic and perhaps propose non-voluntary measures or require a more equal distribution of mitigation burdens across various nations.

While this schematic and exemplary juxtaposition between a more

[5] This category might also comprise techno-fixes that affect the motivational setup of an agent more "intrusively", without "engaging the agent's values": Moral enhancements come to mind here, whose status and precise impact on the agency of a person are widely and controversially discussed [54]. Both nudges and moral enhancements again comprise different types: Thaler and Sunstein define nudges broadly as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentive." [59] Some apps, for example, might send you merely a reminder of your daily emissions to make you more alert of your emission behavior and thus help motivate and monitor changes. Others – like gathering low carbon emission products in a separate section in a supermarket – will lower the obstacle for purchasing those products by simplifying the search for them.

[6] At least, not in the "thick" sense of this word. It is this thick sense, referring to self-realization and positive freedom, that is important for coordination and cooperation [18].

[7] Laura Valentini provides a comprehensive overview of the "ideal vs. non-ideal theory"-debate [25], where she more clearly distinguishes three demarcating features: 1) Full vs. partial compliance, 2) realistic vs. utopian and 3) end-state vs. transitional theory. Applying such fine-grained framework is unfortunately beyond the scope of the present paper.

idealistic and a more realistic approach to climate justice appears straightforward, these distinctions are far less clear cut in actual discourse. The main reason for this is the vagueness of the notion of feasibility.[8] It is often unclear what feasibility means in such complex socio-political contexts: That agents are able to follow a certain moral principle or political obligation or that they are definitely willing to do so [24]? In thei rejection of the idea of corrective justice [23], invoke both technical hurdles and hurdles of motivation (and additional moral concerns).

However, as the following discussion should make clear, when favoring technological efforts such as geoengineering as a more realistic response to non-compliance in terms of effectiveness, ideal theorizing is not only difficult to avoid and oftentimes implicitly adopted, but also hardly ever clearly distinguished as a distinct way of reasoning about climate justice. As suggested, ideal deliberations about climate justice seem futile, since these deliberations are unable to guide and inform effective policymaking.[9] Actors are not willing or able to act in accordance with certain principles (for instance, because they doubt that others are willing to do so). A realistic approach to climate justice, in contrast, takes widespread non-compliance into account and proposes a number of measures that achieve climate mitigation [4]. for example, express this sentiment with regards to geoengineering, when they write:

> "It is precisely because our greenhouse gas emissions are beginning to impose unjust harms on others, [advocates for geoengineering research] argue, that we must consider supplementing mitigation and adaption with geoengineering. **Thus, it should be unsurprising that ideal theory lends no support to geoengineering**; geoengineering's critics, some might say, have been considering the issue from the wrong perspective." [4]; p. 84; own emphasis)

In an ideally just world, the authors argue, geoengineering would not have to be considered, but this is not the world we live in.

Aside from geoengineering, there are a number of other measures that have been considered as a response to current non-compliance. The following list of seemingly more realistic responses to climate change is largely adopted from Simon Caney [2]. Realistic measures comprise, for example, a) climate goal targets are lowered (say from a warming target of 2-degrees to 1,5-degrees), b) responsibility shifts (those who are willing to comply, might have to do more, shoulder more responsibility), c) adaptation to climate change to minimize its damaging consequences rather than attempting to mitigate it, d) compromising other ethical values (destroying biodiversity and undermining aesthetic values e.g. to create hydroelectric power plants etc.; permit transgressions by people who are affected by climate change without sanction (e.g. illegal migration)). Furthermore, there might be ways of "fixing" the compliance problem by, for instance, e) developing economic mechanisms that undermine the benefits of freeriding and, thereby, provide monetary incentives to comply [3], and, lastly, f) by employing technologies that supposedly "fix" climate change and will make compliance unnecessary. Within this last category of more realistic responses to climate change, Caney considers geoengineering as a measure.

However, there are limits to the moral permissibility of each of those responses: Eliminating all climate change targets or overburdening certain groups or institutions with responsibilities and compromising values such as human rights is not permissible even from a realist standpoint. Realistic normative demands that take non-compliance into account cannot be morally arbitrary either. They, too, as [2] argues, must appeal to some normative standard or standard of justice that must be complied with (and of which one can realistically assume that compliance will actually happen) to achieve climate change mitigation.

Against this, proponents of ideal theory might hold that a justification of climate change policies always need higher-order, ethical principles [25]. Others would argue that it is futile to wait for a definitive justification of such principles, as they currently appear groundless and cannot inform policymaking [22]. Such back-and-forth seems exemplary for discussions amongst scholars of ideal and non-ideal climate justice. In the next section, we will clarify how we view this stylized opposition of different categories of climate justice and their relation.

4. Compliance and climate justice

First, it is important to note that while the charges of [2] and [4] are directed at theories of climate justice that promote unfeasible standards, the solutions these authors provide arguably rely to some extent on those theories.[10] The proposed measures by Caney, which are supposedly realistic in spirit, in particular e) (economic incentives) and, in fact, also f), the deployment of techno-fixes such as geoengineering, do not negate the requirements of ideal justice. On the contrary, e) completely endorses the principles of ideal climate justice and aims at developing an incentive structure under which non-compliance with these principles, such as freeriding, does not pay-off. Ideal climate justice —if we were to accept PA, for the sake of argument, as an instance of ideal theorizing—remains the frame of reference for the development of those structures.

Measure e), which is favored as an approach by Caney (p. 37), makes no concession in terms of what is ideally required from reasonable actors. Rather, measure e) might comprise policies (not only economic ones) that increase mutual accountability and enforce commitment to the goals set in PA [26], and thus function as nudges to motivate action in accordance with the agreed upon principles. Equally, measure f) could aim for the same goals as set in international climate agreements such as PA, while achieving these goals via technological means. Hence, the techno-fix response does not deny the desirability of the goals expressed in PA. If PA were representative of a rather idealistic approach to climate change, techno-fixing suggests rather different means to achieving these ideal goals than setting more realistic goals. If it is the voluntariness of one's commitment that makes PA an idealistic framework, techno-fixing suggests in this regard geoengineering as the more realistic means.

Further, the comparative assessment between PA and the suggested strategies provides the justification for the permissibility of moral transgressions as proposed in response d). The comparative argument might be paraphrased like this: Since climate targets as outlined in PA have not been sufficiently realized (best) and climate change will accelerate without intervention leading to manifold harms (worst), we need to locally permit the transgressions of certain norms and the obstruction of certain values (better). If PA were an expression of what is "transcendentally right" to use Sen's terminology, it is not entirely impotent in the justification of those more realistic frameworks [22].

The other responses make more obvious concessions, most clearly a) and b): The latter undermines the fair distribution of responsibility as required by many climate justice theories. The former probably entails the acceptance of some degree of harm – certainly more harm than the 2-degree mark would entail – as a consequence of climate change.

In which way are the other previously discussed responses more realistic than PA? Consider d): Is it indeed realistic to assume that people

[8] Some authors reject the categorical distinction between ideal and non-ideal theories therefore altogether [55].

[9] Being futile is one of the most often raised charges against ideal theory. Amartya Sen suggests that: "The absoluteness of the transcendental 'right' - against the relatives of 'better' and the 'best' – may or may not have a powerful reasoned standing of its own […]. But it does not, of course, help at all – and that is the central point here – in comparative assessments of justice and therefore in the choice between alternative policies." [22]; p. 100).

[10] As Levy correctly points out: "To theorize is to engage in simplification and abstraction — that is, in idealization. And to have a normative vision is to be in at least some small degree idealistic: we imagine that in at least some way, the world might be other than, and better than, it is." [55]; p. 314).

and institutions become more lenient in accepting certain transgressions and, say, shoulder the burdens of migration more willingly than they are currently shouldering direct burdens of climate mitigation efforts? Caney's proposal oftentimes makes implicit assumptions about what people would realistically comply with, assumptions that are not further justified. Perhaps, the question about feasibility is, in fact, not a dividing point between two categorically different types of theories of climate justice, but rather an integral aspect of all approaches to the climate change debate. We will return to this in a moment.

So far, we have discussed PA as presenting infeasible standards that have resulted in non-compliance. However, how reasonable is such view? Rather than comprising a set of abstract principles and aloof ideas that are not action guiding, PA does outline concrete responsibilities and climate targets. It also has been far from impotent: Some nations have indeed complied with the demands set out in PA and the document is a viable basis to hold political decision-makers publicly accountable.[11] It is also reasonable to assume that PA is built on several political and diplomatic compromises and justice constraints. In this light, attacks against the infeasibility of the PA and its alleged idealism do not warrant seeing PA as an exemplar of ideal climate justice theories.[12] Either PA is the product of ideal theorizing that had practical relevance in decision-making, or it is not an ideal theory, but shares with it aspects of infeasibility. The choice seems arbitrary.

Stephen Gardiner suggests in an oft-cited publication that a climate change target must be determined purely based on ethical considerations, which might entail feasibility considerations [27]:

> "At a more practical level, ethical questions are fundamental to the main policy decisions that must be made, such as where to set a global ceiling for greenhouse gas emissions, and how to distribute the emissions allowed by such a ceiling. For example, where the global ceiling is set depends on how the interests of the current generation are weighed against those of future generations; and how emissions are distributed under the global gap depends in part on various beliefs about the appropriate role of energy consumption in people's lives, the importance of historical responsibility for the problem, and the current needs and future aspirations of particular societies." [27]; p. 20)

In the remainder of his article, Gardiner is quite prominently aware of the compliance obstacles ("moral corruption risk") that addressing those considerations on a global scale would face. In other papers, when criticizing KP, he is eager to suggest mechanisms to deal with those obstacles for compliance, which are not target adjustments [28]; p. 39).

In fact, considerable parts of the literature on climate change justice are exemplary of attempts to reconcile justice and feasibility considerations: Numerous authors have developed theories of climate justice and the accompanying policy instruments to realize those theories while preserving justice [29–33]. Posner and Weisbach (2010) prominently focus on the problem that rich countries would not be rationally motivated to mitigate climate change if they obtain no benefits from employing those measures. Darrel Moellendorf [34] suggests against this that richer countries should be motivated to employ those measures, because they would in fact benefit from them: "It is by no means clear why satisfying the right to sustainable development would not be perceived to be in the interest of all states." (p. 179)[13]

Other authors have focused on the feasibility of increased responsibility-taking. Mark Budolfson [30] argues that the assumption of intra-temporal transfers of responsibilities is, in fact, unrealistic or at least not more realistic than inter-temporal transfers.[14] John Broome contends that one should not expect people to be motivated by moral arguments alone. He assumes that individuals will not voluntarily give up some of their welfare without compensation to some degree [29]; p. 47 f.). In order to make climate mitigation happen, one needs economic institutions (he suggests banks that set up bonds) that make such behavior economically rational, which would be a solution that would be both justice-preserving and feasible.

In summary, much of this literature is in fact engaged in discussing what is feasible and how it can be reconciled with justice demands. Therefore, a defense of ideal climate justice as a distinct category of climate justice theories is hard to find. The literature seems largely devoid of purely abstract proposals that merely assess theories of justice without any recognition of feasibility constraints. Discussing who ought to shoulder the burdens of climate mitigation actions and how to distribute responsibilities, does not stop at pondering over how an ideal society or an ideal form of international cooperation would look like. Most climate justice theories that suggest certain models of responsibility distributions try to blend justifications of moral standards with assumptions about what is feasible. This seems only reasonable given the nature of the problem, which is concerned with an urgent risk for large parts of the human population. Seemingly realistic and seemingly idealistic proposals do not disagree on the substance of climate justice, but about what is to be considered feasible.[15]

Thus, authors who propose geoengineering do not need reference to ideal theory. They could be content showing that their proposals are more feasible, effective and ethical than others, without insinuating that those represent categorically different type of approaches to climate justice. This obviously raises the question, whether geoengineering, alongside mitigation and adaption, is indeed a more feasible, effective and ethical solution. Within the limit scope of the present paper, we cannot discuss this question extensively.[16] However, to determine the value of geoengineering, it will help to recall our taxonomy from section 2. There, we argued that geoengineering neither helps to improve compliance, or the effectiveness of limited compliance, but rather sidesteps the compliance problem altogether. In the next section, the literature on ideal theory will help us show that sidestepping moral duties in this way gives rise to residual responsibilities.

[11] https://www.theguardian.com/science/2021/sep/15/governments-falling-short-paris-climate-pledges-study.

[12] Caney correctly points out that the choice of the 2-degree target in PA, might already reflect a non-ideal compromise by climate activists (2016, p. 27).

[13] Moellendorf proposes the "principle of vulnerability reduction" as a central principle for climate justice [34]; p. 182).

[14] Consider Budolfson's reply to the realist assumptions of Posner and Weisbach: "The argument against their view is that either it depends on the assumption that intratemporal pareto-improving transfers are possible within our generation—which is not possible according to mainstream models since everyone in our generation is a loser from optimal emissions reductions—or else if intertemporal transfers are assumed to be feasible, then contrary to the distinguishing characteristic of their view it would in fact be better and feasible to achieve a pareto improvement without transfers from poor to rich." (p. 328 f.).

[15] Our analysis underscores and echoes a sentiment expressed by William Galston: "In this respect, the dispute comes down to competing ways of distinguishing between what is possible and what isn't. Many realists take the view, for example, that certain features of human psychology are fixed, at least until evolutionary forces transform the human species, and that these features restrict the range of feasible political structures. Many moralists believe either that human beings are more malleable than that or that a more favorable upbringing and social circumstances will reinforce the positive elements of human psychology while muting self-interest and aggression. Although this dispute is largely empirical (in the broadest sense of the term), its theoretical consequences are profound." [57], p. 409)

[16] It doesn't necessarily follow from the fact that all geoengineering applications are problematic as duty-sidestepping techno-fixes resulting in residual responsibility, that they are overall equally ethically problematic. The differences in terms of risk and other morally relevant aspects would have to be considered, too. However, taking this into account is beyond the scope of the present paper.

5. The consequences of non-compliance – residual responsibility

As we argued in section 3 and 4, there is no need to identify the normative standards expressed in PA with an ideal theory of climate justice. Non-compliance is a possibility for all kinds of (social) contracts and feasibility is difficult to conceptualize and assess. As we have seen, because of the urgency and practicality of the problem of climate change, theorists of climate justice oftentimes do consider feasibility when justifying which stakeholders ought to shoulder the burdens of climate mitigation actions.

We are now able to close the circle and return to our analysis of geoengineering as a techno-fix. Rather than easing the demands to comply with climate duties, geoengineering supports us side-stepping those duties, thereby relieving us from currently attributed forward-looking responsibilities [35], while possibly creating others.[17] This move, however, as we suggested before, does not relieve us from a backward-looking responsibility that resulted from our initial non-compliance. The fact that geoengineering (at least in the form of Carbon Dioxide Reduction) has become necessary in order to achieve any of the climate goals, is in and of itself a failure to comply with one's initial responsibilities. The literature on ideal theory will help us sharpen this claim about *residual responsibility* in more detail in the following.

Residual responsibility remains an overlooked moral dimension, even if the problem of climate change could be resolved through geoengineering. Residual responsibility is rarely addressed in the literature on geoengineering, which so far has focused on issues of social justice, risk and hubris (for an overview, see [36][37,38].

In the literature on ideal theory, we find a useful distinction of different types of grounds for non-compliance in terms of whether they exculpate that agent involved. Introducing them briefly will pave the way for carving out the concept of residual responsibility. Some grounds for non-compliance are a) extrinsic/external. For instance, you promised to be home for dinner, but you are stuck in an unexpected and unpredictable traffic jam. As a result, what you ought to actually do is different from what you originally ought to do in an ideal situation. In an ideal situation, you ought to be home for dinner. In the non-ideal situation in which you find yourself, you ought to call and communicate that you will be late. If the traffic jam was unpredictable and beyond your control, then you cannot be blamed; you were not able to comply with the normative demand of the promise and since ought implies can, you did not have to be home for dinner. You are exculpated.

Alongside, b) intrinsic/internal grounds for non-compliance with ideal theory are diverse and it is important to keep them separate (for a more extensive treatment, see [24]). On some grounds it holds that you could have complied and thus ought to comply with these grounds. Yet, you can be excused if you do not comply. You ought to rescue a child drowning in a pond. This holds, even if you have to sacrifice your own child [39]. However, you are excused if you do not. The normative force of the claim does not vanish. Unlike the traffic jam that undermines the possibility of your compliance, your capacity to rescue the child does not vanish, but you are not deemed blameworthy.

By contrast, however, there are internal grounds of the sort that make you not comply with what you ideally have to do. You cannot bring yourself to do it for lack of motivation, for instance. It is these internal grounds for non-compliance that a realistic approach to climate change, like geoengineering, tries to render obsolete. These internal grounds neither undermine our capacity to comply like the traffic jam, nor do they give us an excuse for not complying as does the necessity to sacrifice something that is crucial to us and to our identity as a moral agent like losing a child. The normative force of what ideally had to be done remains intact and leaves us with residual responsibility for not complying with what we ideally had to do.

This distinction between external grounds that undermine the normative force of the original duty, internal grounds that are exculpating and those that are not (lack of motivation), is important and shall be explored more extensively in the following. Take, for example, the case of Professor Procrastinate [40]: Professor Procrastinate promises his colleague, editor of an important journal, to review a paper in the future. The paper is offered to him to review, Procrastinate realizes that he is too lazy and will finish the review awfully late or never, neither of which is acceptable. Thus, ideally, Procrastinate had to review a paper, since he promised to accept and review a paper, but knowing that he won't ever finish the review, he should not accept it (in the non-ideal circumstances, in which he doesn't do it).[18]

The question that is usually considered with regard to this example is, what ought he to do: Ideally, it seems, he should accept to review the paper, because this is what he promised. However, since it is not realistic that he does review the paper in time, he should not accept to review it, as this would merely delay the publishing process and increase editor's and author's frustration. We will not discuss the paradox that seems to emerge from this situation. It is important to point out, however, that the normative force of the original responsibility does not vanish just because Procrastinate knows that he is too lazy to keep the promise. Sure, he should not accept the review, but he also should have kept his initial promise. For not delivering on this promise, he is blameworthy: Being lazy does not undermine the capacity to comply with a moral demand (as does being stuck in a traffic) and it arguably also does not provide an excuse (as is the requirement sacrificing something of greater worth - such as one's own child) for not being blameworthy: He should have reviewed a paper and is blameworthy for not doing so. Laziness is not an excuse.

Similarly, our current inability to live up to the standards of even modest climate policies such as PA require (lowering emissions, achieving the 2-degrees mark), which makes some to suggest to lower targets further or to pursue other approaches that do not require compliance, is neither based on a lack of ability that would undermine the normativity of these justice requirements, nor is it an excuse. Geoengineering as a techno-fix might be justified in terms of its effectiveness as a response to the current situation. This is what a problem-oriented approach would suggest, an approach that looks merely forward. However, it must not make us forget that this lack of compliance, is the basis for blameworthiness that has accumulated for not doing what was required.[19]

One might claim that the "techno-fixing through geoengineering"-case is different from the one of Professor Procrastinate: Once the problem of climate change has been successfully solved through geoengineering, catastrophe has been prevented and no one needs to be blamed, especially not those who have been working on and employed the technology that saved the climate. Procrastinate misses out on fulfilling his duty. This has caused harm, or at least so we assume. A new reviewer needs to be found, which leads to waiting time for the author and extra work for the editor. There is also likely frustration and

[17] Note that many scholars arguing for a guided research process towards geoengineering technologies (see for example, [58]) would disagree with this framing. They consider the investigation and advancement of geoengineering as our primary forward-looking responsibility now [49].

[18] Unlike in the actual climate justice debate, where feasibility is messy and ideal and realistic approaches are oftentimes indistinguishable as shown before, in the stylized thought-experiment of Professor Procrastinate non-compliance for internal reasons is taken as presupposition. This accentuates the categorical difference between ideal and non-ideal behaviour and helps to carve out their implications.

[19] The view presented here differs crucially from that of Baard and Wikman-Svahn [56]: They argue (referencing Bernard Williams) that you are not off the hook, when you haven't complied to develop a better solution. We, on the contrary, argue that when you have found a technology that helps you avoid your obligation altogether, you are not freed from residual responsibility.

disappointment on the side of the editor for having been let down.

In the case of climate change, the obligation and duty to mitigate might shift if geoengineering is successfully applied. There will be no longer the same need to comply with the standard mitigation duties. If the editor blames Procrastinate, she expresses her moral sentiments, articulates a judgment about his misconduct and her disapproval. This might serve the purposes of reforming him, to do better next time and also of displaying that such behavior is intolerable [41]. What would be the purpose of blame in the context of climate change? Under current circumstances, the attribution of blame clearly serves to motivate the agents that are doing too little to mitigate. But, once this is no longer required, is there still a function for blame?

Clearly, there could still be the expressivist function of blame, namely an articulation of disapproval that the alleged collective duties have not been fulfilled. The question then arises though what is the object of this disapproval? Why is not fulfilling these initial duties reprehensible, if the "problem" can be partially solved with geoengineering? On the one hand, we could still consider the inaction of a majority of the addressed population to respond to climate change a massive form of reckless complacency. Geoengineering as a techno-fix solution appeared on the stage beyond their control and one might, therefore, count them morally lucky that no major harms have occurred. On the other hand, being recklessly complacent in the face of a global crisis is reprehensible, even if it turns out due to matters beyond most peoples' control that the problem can still be solved.

However, and more importantly, there is already harm resulting from climate mitigation inaction [42]. It is difficult to exactly pinpoint its scale, but harm and costs of climate change become increasingly obvious. Hence, the non-compliance is not only a form of reckless complacency, which would be in and of itself morally reprehensible, it also has caused harm and is, therefore, a clear instance of wrongdoing. Culpable wrongdoing is a ground for blame as much in the context of climate change as it is in the case of Professor Procrastinate. Being morally lucky in the sense that the (unintended) harms one caused end up "solving" themselves, does not absolve one from the moral responsibility and blame.

In the previous section, we have tied our analysis, of sidestepping non-compliance with geoengineering, to the concept of blameworthiness. Our discussion of the case of Professor Procrastinate has strongly suggested using this concept for the present context. However, a richer and more suitable terminology is the concept of "residual responsibility" that captures a variety of other reactive dimensions; cognitive, emotional and behavioral. With reference to the Procrastinate case, the concept of residual responsibility would also capture justified feelings of guilt and regret by the Professor, which are dimensions of the broader responsibility concept but clearly distinct from blame. In the last section, we will briefly outline the weight and implications of residual responsibility for the context of climate change and geoengineering.

6. The weight of residual responsibility

Having shown that not fulfilling one's duties, even if there are other justified ways to respond to a problem, does not absolve one from residual responsibility, raises further questions: What is the weight of this residual responsibility? Does it add anything to the discussion about the desirability or permissibility of geoengineering and whether we should apply it? There are three possible implications that shall be briefly discussed in the following.

First, the residual blameworthiness for not living up to the demands of even modest policy frameworks such as PA can become the basis for future claims (once the climate change problem has hopefully been resolved) to rectify or compensate for damage. This is because damage has already occurred through the omission of taking immediate and more radical action or the employment of alternative measures such as geoengineering. These measures were considered necessary because of non-compliance. The literature on ideal theory has helped us to carve out this point: Whatever the consequences of those measures – be it the corrosion of faith in collective moral action (see above) or direct increments of inequality through those technologies [43,44] – the reasons for their employment are grave, inexcusable omissions of responsibility by current generations, which had the ability to act differently and prevent a need for them. One might agree that the ideal of climate justice is not a viable guide for current climate action. However, such ideal is important, because it will provide normative guidance in the long run for judging and holding responsible those people, whose actions (or better omissions) have made it necessary to consider geoengineering and all its consequences as reasonable alternatives in the first place.[20]

Second, in line with the taxonomy of techno-fixes, which we have introduced in the beginning, we can now clearly see that – leaving aside the associated risks and effectiveness of those measures – it would be preferable to use a techno-fix that does not sidestep compliance. Rather, techno-fixes should be employed that engage the values and commitments of moral agents in a way that they take up the responsibility of compliance with climate mitigation duties voluntarily. This would not be the case with enhancers, which make some peoples' acts more effective and less costly for them but won't alter the motivations and behavior of most other agents. Their omitting behavior remains the same. However, this would be the case for many nudging technologies: It might still be blameworthy that many people needed the extrinsic help of nudging to increase their motivational setup to comply with their climate mitigation duties. However, since they would eventually comply in a way that aligns with their own values and preferences, this would certainly be less blameworthy, than if they never did. The same would apply to policy architectures that changes the incentive structures and, thus, increases the benefits of compliance [3].

Third, residual responsibility also provides grounds for new forward-looking responsibilities. In this sense, the relation between forward- and backward-looking responsibilities can be conceived of as a spiral; Procrastinate's refusal to review might arguably give rise to the duty to propose a different reviewer to the editor in other to facilitate the transition more quickly. In the context of geoengineering, the backward-looking, residual responsibility for non-compliance might give rise to the responsibility to care for and maintain the technology of geoengineering, if its application is seen as a direct result of that non-compliance. Several years ago Pak-Hang Wong [45], has raised awareness that the technology of geoengineering requires supervision, maintenance and long-term catering and that this is rarely addressed in the literature. It seems natural to assume that if the reason for geoengineering's application is non-compliance, it is the non-complying peoples' responsibility to maintain this technology.

The previous suggestions are not intended to articulate which moral charges can definitively be brought against people, institutions or states that have been non-compliant, if geoengineering turns out to be the most reasonable response to rising temperatures. Rather, they at least show that the notion of residual responsibility carries some weight and should be considered in the debate about the permissibility and desirability of geoengineering applications.

7. Conclusions

In the present paper, we have discussed geoengineering as techno-fix for climate change, which is proposed as a consequence of widespread non-compliance with climate mitigation duties. While it seemed that the emphasis on non-compliance invited more realistic proposals to climate change and suggested the futility of ideal climate justice theories, we have shown that the feasibility question does not divide different types of climate justice theories (ideal and non-ideal ones), but is in fact

[20] This reasoning is clearly conditional: To make this claim sound, geoengineering would have to be the most reasonable of all available alternatives, or, in fact, the only alternative.

integral to the climate justice debate and plays a role in many, if not all, proposals that are being seriously discussed. Stressing a categorical difference between climate justice theories that are more modest in their demands to those that are more daring creates an artificial divide that is theoretically inviable and unproductive.

We have shown that employing geoengineering as a techno-fix means delegating the forward-looking duty of mitigating climate change to another (technological) agent. We have also shown in the last section that this does not underminet the backward-looking responsibility for having failed to live up to the initial demands of even modest climate mitigation duties and sustainability policies in the first place. This remaining residual, backward-looking responsibility can give rise to claims for compensation for the harms that have already occurred and for the risks and consequences that might occur as a result of geoengineering deployment. Mitigating or techno-fixing climate change with geoengineering shall not make us forget that we had no excuses nor were we unable to act according to our duties. This might also give rise to new forward-looking responsibilities, namely to maintain and supervise those technologies. Lastly, it might provide reasons to prefer non-technological means to respond to the compliance problem or to prefer techno-fixes that engages moral agents so that they are more willing to take up their mitigation duties.

In light of the previous reasoning, two questions remain for future research: Climate change is obviously a "problem of the many hands" [46], meaning that different agents will have to be attributed with different responsibilities, if the responsibility allocation ought to be fair. This causes both massive theoretical and practical problems. The same theoretical and practical problems of fair allocation will emerge, when the compensatory and maintenance duties ought to be distributed that arise from residual responsibility, which we uncovered and detailed in the last section. It would be clearly unfair to distribute the burdens of those duties equally over the agents that have been addressed with climate mitigation duties. However, it is far from clear how else to distribute them.

Secondly, while residual responsibility has some weight as we have argued in the last section, it remains a future task to determine in comparison with other arguments for or against the deployment of geoengineering just how weighty residual responsibility is in this equation. This requires a comparative view on the risks and benefits involved in the various geoengineering technologies as much as a consideration of the risks and benefits of the technological and non-technological alternatives of geoengineering.

Author statement

Martin Sand is the main author of this paper. He led and coordinated all phases of the research (conceptualization, analysis and interpretation), writing and revision process and was also actively involved in them. **Ben Hofbauer** and **Joost Alleblas** were to an equal degree involved as co-authors and contributed significantly to the conceptualization and analysis of the research and to the writing of the draft of this paper and its current revised version.

Funding information

This work is part of the research program *Ethics of Socially Disruptive Technologies*, which is funded by the Gravitation program of the Dutch Ministry of Education, Culture, and Science and the Netherlands Organization for Scientific Research (NWO grant number 024.004.031). Joost Alleblas' contribution to this paper has been generously supported by the European Commission funded ERC Project "Design for Changing Values" under the grant agreement No. 788321.

Data availability

No data was used for the research described in the article.

References

[1] H. Fekete, T. Kuramochi, M. Roelfsema, M.d. Elzen, N. Forsell, N. Höhne, L. Luna, F. Hans, S. Sterl, J. Olivier, H. van Soest, S. Frank, M. Gusti, A review of successful climate change mitigation policies in major emitting economies and the potential of global replication, Renew. Sustain. Energy Rev. 137 (2021), 110602, https://doi.org/10.1016/j.rser.2020.110602.
[2] S. Caney, Climate change and non-ideal theory - six ways of responding to non-compliance, in: C. Heyward, D. Roser (Eds.), Cimate Justice in Non-ideal World, Oxford University Press, 2016, pp. 21–42.
[3] W.D. Nordhaus, Climate clubs: overcoming free-riding in international climate policy, Am. Econ. Rev. 105 (4) (2015) 1339–1370, https://doi.org/10.1257/aer.15000001.
[4] D. Morrow, T. Svoboda, Geoengineering and non-ideal theory, Publ. Aff. Q. 30 (1) (2016) 83–102.
[5] S.M. Gardiner, Ethics and geoengineering: an overview, in: L. Valera, J.C. Castilla (Eds.), Global Changes: Ethics, Politics and Environment in the Contemporary Technological World, Springer International Publishing, 2020, pp. 69–78, https://doi.org/10.1007/978-3-030-29443-4_7.
[6] S.M. Gardiner, Ethics and climate change: an introduction, WIREs Clim. Change 1 (1) (2010) 54–66, https://doi.org/10.1002/wcc.16.
[7] Nils Markusson, McLaren Duncan, David Tyfield, Towards a cultural political economy of mitigation deterrence by negative emissions technologies (NETs), Global Sustain. 1 (2018), https://doi.org/10.1017/sus.2018.10.
[8] Duncan McLaren, Mitigation deterrence and the 'moral hazard' of solar radiation management, Earth's Future 4 (12) (2016) 596–602, https://doi.org/10.1002/2016EF000445.
[9] E. Morozov, To save everything, click here: the folly of technological solutionism, PublicAffairs, (2014).
[10] M. Huesemann, J. Huesemann, Techno-Fix: Why Technology Won't Save Us or the Environment, New Society Publishers, 2011.
[11] M. Sand, K.R. Jongsma, The usual suspects: why techno-fixing dementia is flawed, Med. Healthc. Philos. 20 (1) (2017) 119–130, https://doi.org/10.1007/s11019-016-9747-9.
[12] D.W. Keith, A Case for Climate Engineering, The MIT Press, 2013, https://doi.org/10.7551/mitpress/9920.001.0001.
[13] A. Marquardt, B. Kravitz, G. Stenchikov, Benefits, risks, and costs of stratospheric geoengineering, Geophys. Res. Lett. 36 (19) (2009), https://doi.org/10.1029/2009GL039209.
[14] A.M. Weinberg, Can technology replace social engineering? in: E. Katz, A. Light, W. B. Thompson (Eds.), Controlling technology, first ed., Prometheus books, 1991, p. 286.
[15] M. Alfano, P. Robichaud, Nudges and other moral technologies in the context of power: assigning and accepting responsibility, in: D. Boonin (Ed.), The Palgrave Handbook of Philosophy and Public Policy, Springer Verlag, 2018, pp. 235–248.
[16] D. Hagmann, E.H. Ho, G. Loewenstein, Nudging out support for a carbon tax, Nat. Clim. Change 9 (2019) 484–489. https://doi-org.tudelft.idm.oclc.org/10.1038/s41558-019-0474-0.
[17] George Loewenstein, Nick Chater, Putting nudges in perspective, *Behavioural Public Policy*1 1 (2017) 26–53.
[18] T. Goodwin, Why we should reject 'nudge, Politics 32 (2) (2012) 85–92.
[19] Frank Biermann, Jeroen Oomen, Aarti Gupta, Saleem H. Ali, Ken Conca, Maarten A. Hajer, Prakash Kashwan, et al., Solar geoengineering: the case for an international non-use agreement, WIREs Clim. Change 13 (3) (2022) e754, https://doi.org/10.1002/wcc.754.
[20] Clive Hamilton, No, we should not just 'at least do the research', Nat. News 496 (7444) (2013) 139, https://doi.org/10.1038/496139a.
[21] Augustin Fragnière, Stephen Gardiner, Why Geoengineering Is Not 'Plan B.' in , 15–31. Preston, Christopher J. 2016. *Climate Justice and Geoengineering: Ethics And Policy In the Atmospheric Anthropocene*, Rowman & Littlefield, 2016.
[22] A.K. Sen, The Idea of Justice, Penguin Books, 2010.
[23] E.A. Posner, C.R. Sunstein, Climate change justice, Georgetown Law J. 1565 (96) (2008) 1565–1612.
[24] D. Estlund, Utopophobia - on the limits (if any) of political philosophy, Princeton University Press, 2020.
[25] L. Valentini, Ideal vs. Non-ideal theory: a conceptual map, Philos. Compass 7 (9) (2012) 654–664.
[26] S.I. Karlsson-Vinkhuyzen, M. Groff, P.A. Tamás, A.L. Dahl, M. Harder, G. Hassall, Entry into force and then? The Paris agreement and state accountability, Clim. Pol. 18 (5) (2018) 593–599, https://doi.org/10.1080/14693062.2017.1331904.
[27] S.M. Gardiner, A perfect moral storm: climate change, intergenerational ethics and the problem of moral corruption, Environ. Val. 15 (3) (2006) 397–413. http://www.jstor.org/stable/30302196.
[28] S.M. Gardiner, The global warming tragedy and the dangerous illusion of the Kyoto Protocol, Ethics Int. Aff. 18 (1) (2004) 23–39.
[29] J. Broome, Climate Matters: Ethics in a Warming World, W. W. Norton & Company, 2012.
[30] M. Budolfson, Political realism, feasibility wedges, and opportunities for collective action on climate change, in: M. Budolfson, T. McPherson, D. Plunkett (Eds.), Philosophy and Climate Change, Oxford University Press, 2021, pp. 323–345, https://doi.org/10.1093/oso/9780198796282.003.0015.
[31] M. Frisch, Climate change justice, Philos. Publ. Aff. 40 (3) (2012) 225–253, https://doi.org/10.1111/papa.12002.
[32] J. Broome, Do not ask for morality, in: A. Walsh, S. Hormio, D. Purves (Eds.), The Ethical Underpinnings of Climate Economics, Routledge, 2016, pp. 9–21.

[33] E.A. Posner, D.A. Weisbach, Climate Change Justice, Princeton University Press, 2010.
[34] D. Moellendorf, Climate change justice, Philos. Compass 10 (3) (2015) 173–186, https://doi.org/10.1111/phc3.12201.
[35] I. van de Poel, M. Sand, Varieties of responsibility: two problems of responsible innovation, Synthese 198 (19) (2021) 4769–4787, https://doi.org/10.1007/s11229-018-01951-7.
[36] W.C.G. Burns, A.L. Strauss (Eds.), Climate Change Geoengineering. Philosophical Perspectives, Legal Issues, and Governance Frameworks, Cambridge University Press, 2013.
[37] A. Pamplany, B. Gordijn, P. Brereton, The Ethics of geoengineering: a literature review, Sci. Eng. Ethics 26 (6) (2020) 3069–3119, https://doi.org/10.1007/s11948-020-00258-6.
[38] S.M. Gardiner, A. Fragnière, Geoengineering, political legitimacy and justice, Ethics Pol. Environ. 21 (3) (2018) 265–269, https://doi.org/10.1080/21550085.2018.1562524.
[39] J.M. Fischer, N.A. Tognazzini, The physiognomy of responsibility, Philos. Phenomenol. Res. 82 (2) (2011) 381–417.
[40] F. Jackson, R. Pargetter, Oughts, options, and actualism, Phil. Rev. 95 (2) (1986) 233–255.
[41] D.J. Coates, N.A. Tognazzini, The nature and Ethics of blame, Philos. Compass 7 (3) (2012) 197–207.
[42] J. Tollefson, Climate Change Is Hitting the Planet Faster than Scientists Originally Thought [News], Nature, 2022.
[43] J.S. Dryzek, J. Pickering, The Politics of the Anthropocene, Oxford University Press, 2019.
[44] L. Schneider, Fixing the climate? How geoengineering threatens to undermine the SDGs and climate justice, Development 62 (1) (2019) 29–36, https://doi.org/10.1057/s41301-019-00211-6.
[45] P.-H. Wong, Maintenance required: the Ethics of geoengineering and post-implementation scenarios, Ethics Pol. Environ. 17 (2) (2014) 186–191.
[46] I. van de Poel, L. Royakkers, S.D. Zwart (Eds.), Moral Responsibility and the Problem of Many Hands, Taylor & Francis, 2015.
[47] P.J. Crutzen, Albedo enhancement by stratospheric sulfur injections: a contribution to resolve a policy dilemma? Climatic Change 77 (3) (2006) 211, https://doi.org/10.1007/s10584-006-9101-y.
[48] J. Hartmann, A.J. West, P. Renforth, P. Köhler, C.L. De La Rocha, D.A. Wolf-Gladrow, H.H. Dürr, J. Scheffran, Enhanced chemical weathering as a geoengineering strategy to reduce atmospheric carbon dioxide, supply nutrients, and mitigate ocean acidification, Rev. Geophys. 51 (2) (2013) 113–149.
[49] J. Horton, D. Keith, Solar Geoengineering and Obligations to the Global Poor. *Climate Justice and Geoengineering: Ethics And Policy in the Atmospheric Anthropocene*, 2016, pp. 79–92.
[50] M. Hulme, Can Science Fix Climate Change?: A Case against Climate Engineering, Polity Press, 2014.
[51] F. Lecocq, H. Winkler, J.P. Daka, S. Fu, J.S. Gerber, S. Kartha, V. Krey, H. Lofgren, T. Masui, R. Mathur, J. Portugal-Pereira, B.K. Sovacool, M.V. Vilariño, N. Zhou, Mitigation and development pathways in the near- to mid-term, in: P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley (Eds.), IPCC, 2022: 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, Cambridge, UK and New York, NY, USA, 2022, https://doi.org/10.1017/9781009157926.006.
[52] Joseph Jebari, , Olúfẹmi O. Táíwò, Talbot M. Andrews, Valentina Aquila, Brian Beckage, Mariia Belaia, Maggie Clifford, et al., From moral hazard to risk-response feedback, Clim. Risk Manag. 33 (January) (2021), 100324, https://doi.org/10.1016/j.crm.2021.100324.
[53] D. Amelung, J. Funke, Dealing with the uncertainties of climate engineering: warnings from a psychological complex problem solving perspective, Technol. Soc. 35 (1) (2013) 32–40, https://doi.org/10.1016/j.techsoc.2013.03.001.
[54] L.E. Frank, What do we have to lose? Offloading through moral technologies: moral struggle and progress, Sci. Eng. Ethics 26 (1) (2020) 369–385, https://doi.org/10.1007/s11948-019-00099-y.
[55] J.T. Levy, There is no such thing as ideal theory, Soc. Philos. Pol. 33 (1–2) (2016) 312–333.
[56] P. Baard, P. Wikman-Svahn, Do we have a residual obligation to engineer the climate, as a matter of justice? in: C.J. Preston (Ed.), Climate Justice and Geoengineering: Ethics and Policy in the Atmospheric Anthropocene Rowman & Littlefield, 2016, pp. 49–62.
[57] W.A. Galston, Realism in political theory, Eur. J. Polit. Theor. 9 (4) (2010) 385–411.
[58] National Academies of Sciences, Engineering (NASEM), Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance, 2021.
[59] R.H. Thaler, C.R. Sunstein, Nudge: Improving Decisions about Health, Wealth and Happiness, Penguin, 2009.