Philosophy & Technology (2025) 38:177
https://doi.org/10.1007/s13347-025-01010-3

RESEARCH ARTICLE

Doubling Down on Emissions Reductions

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Received: 29 July 2025 / Accepted: 28 November 2025

Abstract

Especially in the public discourse, there seems to be a tendency to focus not on mitigation, but on the supplementary interventions – adaptation, negative emissions technologies, and solar radiation management – to tackle climate change. Arguably, this elicits a moral hazard, whereby reliance on the supplementary interventions results in mitigation deterrence. In this paper, I will argue that we should *double down* on urgent and ambitious emissions reductions to minimise our reliance on adaptation; reserve NETs for covering the most-difficult-to-abate and legacy emissions; and avoid SRM (or, in the worst case, minimise our reliance on it as a fallback). The reasons for this are that there are severe constraints to the potential of the supplementary interventions, and reliance on them results in a transfer of risks from today's affluent decision-makers to poor, vulnerable, and future people, as well as non-human nature. I will take a fresh look at the moral hazard argument and argue that, interpreted as a structural process, it can be traced back to the dominant liberal-capitalist worldview: while ambitious decarbonisation challenges materialistic freedoms and the vested interests in a fossil-fuel based economy, the supplementary climate interventions leave the liberal-capitalist worldview virtually unchallenged. Finally, I highlight the large untapped potential of mitigation options and indicate areas for further research regarding mitigation. We should be aware that some mitigation options can also result in risk transfers, but these are not inherent to mitigation – in contrast to the supplementary interventions – and can thus be avoided.

Keywords Climate ethics · Mitigation · Moral hazard · Adaption · Negative emissions technologies · Solar radiation management

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Published online: 12 December 2025

1 Introduction

There is no doubt that climate change mitigation by reducing the emissions of greenhouse gases is *the* priority of climate policy. Nonetheless, this conviction seems to be eroding, especially in the public discourse, but to some extent in the academic debate as well. There seems to be a tendency to take the failure of mitigation for granted, accompanied by proliferating calls to shift focus to adaptation, negative emissions technologies (NETs) and solar radiation management (SRM), which I will collectively call the *supplementary climate interventions*. While I have no knowledge of anyone in the academic debate seriously advocating for one of these supplementary interventions without ambitious emissions reductions, there is also a lot of scepticism regarding the effectiveness of mitigation, driving the shift of focus towards the supplementary measures. I will give anecdotal evidence for this tendency in Sect. 2, which indicates the existence of a *moral hazard*.

Put briefly, the moral hazard argument boils down to the concern that reliance on adaptation, NETs and SRM will reduce our commitment to urgent and ambitious decarbonisation.[1,2] On the one hand, the moral hazard can be interpreted as a psychological effect on individuals whose commitment to mitigation may be weakened if they were to see the supplementary measures as a convenient substitute for more difficult emissions reductions. On the other hand, it can be interpreted as a structural process generating institutional, political and economic decisions that delay mitigation. I will return to this distinction in Sect. 3, but in each case, the moral hazard is problematic, because there are empirical and moral reasons for keeping reliance on the supplementary interventions as small as possible by a strong commitment to ambitious mitigation.

Another relevant distinction (especially in the case of SRM) is the one between research regarding the supplementary measures versus their actual deployment. It is the mere *prospect* of potentially deploying the supplementary measures which may already result in mitigation deterrence and there is a risk that research will amplify this effect. To clarify: I believe that the supplementary climate interventions have crucial roles to play in climate policy, but their research and deployment should remain *supplementary* to ambitious emissions reductions, rather than being regarded as a full or partial *substitute*. The question, in my view, is not whether we will need adaptation, NETs and/or SRM to successfully tackle climate change, but rather how we can keep our reliance on adaptation as limited as possible (even though it is obvious that the current state of the climate already necessitates substantial deployment); reserve NETs for covering the most-difficult-to-abate and legacy emissions; and avoid SRM (or, if full avoidance is not feasible, minimise our reliance on it as a fallback). In this context, I remain a supporter of research into adaptation, NETs and SRM, but I will also discuss the role of research in generating the moral hazard (Sect. 3).

[1] For a thorough discussion of characterisations and definitions of "moral hazard", see Hale (2012).

[2] To my knowledge, the moral hazard argument has not been discussed in the literature with respect to adaptation. A notable exception is Jamieson (2005, 222–229), who does not use the term "moral hazard", but discusses the main issues at stake.

The aim of this paper is to argue for strengthening our commitment to – for *doubling down* on – ambitious and urgent emissions reductions as the central pillar of any climate policy. In addition to contributing to the literature on climate ethics, I hope to reach policymakers for whom, in view of the structural (social, economic and political) factors that mar urgent and ambitious decarbonisation, it may be tempting to shift focus to adaptation, NETs and SRM.

In the following section I will discuss adaptation, NETs and SRM. I will give anecdotal evidence for the existence of the moral hazard with respect to each of them, discuss the limits to their deployment and transfers of risk involved. Some of these arguments have been discussed in the literature, but I aim to fill in the remaining gaps. Moreover, examining the limits of and the risk transfers involved in each of these supplementary climate interventions in one place will reveal important parallels between them. This will benefit the academic debate as well as climate policy by making clear that it would be ineffective and morally problematic to reduce our commitment to urgent and ambitious emissions reductions based on undue reliance on the supplementary measures. Subsequently, I will take a fresh look at the *moral hazard argument*, debunk scepticism regarding it, and discuss significant arguments that have remained sparsely developed in the literature. In Sect. 4, I will argue that we should indeed double down on mitigation: despite some (avoidable) risks, there is still a huge untapped potential of mitigation options and I will indicate some areas for future, interdisciplinary research regarding mitigation.

2 Adaptation, NETs and SRM

In this section, I will discuss adaptation, NETs, and SRM, respectively. I will illustrate the existence of the moral hazard regarding each of these with anecdotal evidence. I will highlight the most important practical and geophysical constraints to their potential. Moreover, I will argue that overly relying on these supplementary climate interventions constitutes a morally problematic transfer of risk. Shue (2017a), 2018) has developed this argument with respect to NETs, others have made parallel arguments with respect to SRM (for example, Fragnière and Gardiner (2016, 22); Gardiner (2011, 2013); Svoboda (2017, Chap. 2) and I will argue that it is an important issue regarding adaptation as well. More specifically, in all three cases, the risk is transferred *from* today's affluent and polluting people who save themselves the costs and efforts of ambitious emissions reductions. Those *to* whom the risk is transferred are vulnerable, poor and future people, as well as nonhuman nature, who may suffer most from the risks involved in deploying these interventions and from the risk of their failure. This constitutes a serious injustice.

2.1 Adaptation

In view of the already occurring impacts of climate change and the unavoidable future warming, a lot of attention has been devoted to adaptation. Adaptation research has proliferated since the IPCC's Second Assessment Report officially defined it in 1996 (Bassett & Fogelman, 2013, p. 48; IPCC, 2022a, p. 167–168). Moreover, while

adaptation was sidelined in the early decades of the UNFCCC, the need to address it with the same priority as mitigation was enshrined in the Cancun Agreements (UNFCCC 2011, 2(b); see Heyward, 2017, p. 474–475).

Adaptation is essential to increase resilience and reduce vulnerability of victims of climate change and must obviously supplement emissions reductions. However, some have gone further to argue that investing in adaptation could substitute for mitigation. For example, the Flemish Minister for the Environment Zuhal Demir has been highly critical of the ambitious emissions reduction targets imposed by the European Green Deal, refused to implement these to their full extent, and sought the confrontation with the European Commission (Merckx, 2024). Moreover, she has publicly stated that adaptation is more important than mitigation for Flanders and for Europe as a whole (Demir in Vlaams Parlement 2023).

The academic debate on adaptation is ongoing, but by my knowledge, no climate scholar would argue that investing in adaptation could substitute for mitigation. It is clear in the literature that it remains *supplementary* to mitigation and the most decisive reasons why reliance on adaptation cannot compensate for reduced mitigation ambition are rather uncontroversial.[3] First, unmitigated climate change will result in impacts to which we cannot adapt, such as impacts that become too large or too abrupt (for example, a collapse of the Atlantic Meridional Overturning Circulation). In addition, positive feedback loops (such as emissions from the thawing permafrost) result in ever-exacerbating climatic changes. Second, the lower the mitigation ambitions, the more adaptation will be needed, increasing its costs, which moreover escalate with higher warming. Hence, for geophysical, technological and financial reasons, adaptation without ambitious mitigation would be ineffective (Adger et al., 2009, p. 337).

The main moral objection to shifting attention from mitigation to adaptation is the fundamental injustice entailed by increased reliance on adaptation: it would be 'an application of the "polluted pay" principle, rather than the "polluter pays" principle' (Jamieson, 2005, p. 223). Poor and vulnerable victims of climate change will bear the burdens of adaption, while they are the least responsible for climate change. One could argue that this injustice could be avoided if the polluters and/or the wealthy finance adaptation, but the international community is far from fulfilling this duty. UNEP (2024, p. 49) estimates the finance needs for developing countries to be US$215–387 billion per year this decade, but the global public adaptation finance flows to developing countries were a mere US$27.5 billion in 2022. This is a global injustice in itself, but more fundamentally, *even if* the affluent polluters were to appropriately fund adaptation, the vulnerable would still bear the burden of implementing the actual adaptation measures, with significant risks for and impacts on their lives. Hence, reducing mitigation ambitions and increasing reliance on adaptation results in a problematic transfer of risks from those responsible for climate change to its victims.

First, adaptation leaves residual risks that are inevitably borne by those who are forced to adapt. Climate impacts are unpredictable and may exceed expectations,

[3] For more drtails on the ethics of adaptation, see for example Heyward (2017) and the essays in the collection edited by Adger and colleagues (2009).

potentially rendering adaptation measures insufficient or ineffective. There is also the risk of *maladaptation*, worsening the situation (Schipper, 2020). Many adaptation strategies do not address the root causes of vulnerability, which are often socio-cultural (such as gender or class norms). As discussed above, there may be climatic changes to which it is impossible to adapt. Ultimately, these risks fall primarily on the supposed beneficiaries of adaptation.

Second, the cultural dimension of adaptation should be acknowledged (Heyward, 2017). The loss or significant physical changes to places can result in social and cultural losses, which have often been overlooked in adaptation discourse. For example, to some extent, Inuit groups may be able to adapt to the physical changes in their environment– including by using tents instead of igloos as temporary shelters; or by replacing overland travel over thinning ice by travel by boat. Nonetheless, traditional practices are becoming unviable due to climate change, and the Inuit members experience this as a significant loss in itself. Their way of life and their cultural identity are being uprooted or lost, a cost that cannot be compensated.[4]

Heyward (2017, p. 480) mentions that including measures to preserve the distinctive cultural identity of vulnerable peoples in adaptation has implications for the balance between adaptation, mitigation and other responses to climate change. She does not elaborate this point, but taking the cultural dimension seriously shows that adaptation has limits which, while subjective, are fully real for those experiencing them (Adger et al., 2009, p. 348). This reinforces the case for urgent and ambitious mitigation because it is the most effective way to prevent the impacts on climate change on cultural identity of vulnerable peoples in the first place.

In sum, adaptation is an essential climate policy strategy that should supplement mitigation. However, reducing mitigation ambitions based on an increased reliance on adaptation will not be effective and result in a morally problematic transfer of risks from affluent and polluting people to vulnerable, poor and future people, and non-human nature. Therefore, the need for adaptation should be minimised through urgent and ambitious emissions reductions.

2.2 Negative Emissions Technologies (NETs)

Recent years have seen an increasing prominence of NETs in the climate debate. The two methods that are discussed most are bioenergy with carbon capture and storage (BECCS), which extracts bioenergy from biomass while capturing and storing the carbon emitted, and direct air carbon capture and storage (DACCS), whereby chemical or other processes capture carbon directly from the atmosphere and store it.

The consensus seems to be growing that NETs will inevitably form a significant part of future climate policy (for example Callies & Moellendorf, 2021, p. 138–139; UNEP, 2023; von Rothkirch et al., 2024). In its Sixth Assessment Report, the IPCC

[4] A possible objection here is that acknowledging the cultural dimension does not question the value of the practices that demand preservation. For example, abandoning human settlement in certain vulnerable places (such as some coastal regions) may be experienced as a profound loss, while it could also be highly beneficial for biodiversity. Ethical reflection on these issues is appropriate, yet the fact remains that in these cases, it is the *victims* of climate change who are forced to give up their way of life due to the (at least equally morally problematic) polluting way of life of the affluent.

(2023, p. 85, my emphasis) states that while reaching net zero GHG emissions requires ambitious emissions reductions, 'the deployment of [NETs] to counterbalance *hard-to-abate residual* emissions (e.g., some emissions from agriculture, aviation, shipping, and industrial processes) is unavoidable.' Unfortunately, discussions about NETs often neglect the IPCC's crucial qualification that we are discussing counterbalancing hard-to-abate residual emissions *only*.[5]

Indeed, in their so-called "Net Zero" strategies, industries and governments rely or even over-rely on future large-scale deployment of NETs as an alternative to making steep emissions reductions today (Anderson & Peters, 2016, p. 183; Deprez et al., 2024, p. 484; Self et al. 2023, p. 1). McLaren and colleagues (2019, p. 1) see clear evidence 'that emissions reductions can be deterred or delayed by efforts and suggestions to use NETs to sustain fossil fuels,' and argue that the failure to distinguish between emissions reductions and negative emissions targets has already hampered climate policy. For instance, the United Kingdom aims to remove 75–81 $MtCO_2$ by 2050 by NETs, displaying 'a considerable reliance on removals, which could pose a delivery risk' (Climate Action Tracker 2024). Similarly, Carton and colleagues (2023, p. 6–7) report that the inclusion of NETs in assessment models already substitutes for emissions reductions on very large scales. Hence, the promise of future negative emissions has already resulted in mitigation deterrence.

It may seem irrelevant whether the accumulation of greenhouse gases is abated by emissions reductions or NETs. However, heavily relying on NETs is problematic because they are unlikely to be feasible at the required scale given land, energy and water requirements as well as economic costs (Pires, 2019). This argument has already been discussed in the climate ethics literature,[6] but allow me to make it more vivid with recent figures.

On the one hand, BECCS will be able to counterbalance only 0.7–1.2 Gt CO_2 per year at low risk to biodiversity and land (Deprez et al., 2024, p. 484). More expansive deployment would bring about significant risks regarding biosphere integrity, freshwater use, food security, and rights of Indigenous and local peoples (Anderson & Peters, 2016, p. 183; Deprez et al., 2024, p. 484–485). Compared to the 2024 global total of 37.8 Gt (IEA, 2025, p. 31), this means that only about 1.9–3.2% of annual emissions can be counterbalanced with BECCS at low risk. In the case of DACCS, since any given facility can eventually be expected to extract only one million tonnes of CO_2 (or 0.001 Gt) per year on average (Ho, 2023, p. 9), many thousands of facilities would be required to counterbalance a substantial proportion of global emissions. Therefore, 'deploying them [DACCS] to remove CO_2 from the atmosphere is pointless until society has almost completely eliminated its polluting activities' (Ho, 2023, p. 9).

In the academic debate, NETs are mostly assumed to be deployed only to cover *hard-to-abate residual* emissions, so let us look at these. Buck and colleagues (2023, p. 352) estimate the residual emissions to be over 12 Gt CO_2 per year globally, which

[5] There is no consistent definition of "residual emissions" (Buck et al. 2023) or "hard-to-abate emissions"; my categorisation of emissions in this section as "*not*-hard-to-abate", "hard-to-abate" and "most-difficult-to abate" is merely indicative.

[6] See especially Anderson and Peters (2016); Shue (2017a), 2018).

is slightly less than a third of total annual emissions.[7] The International Energy Agency (IEA 2021, p. 79) projects that 1.6 Gt CO_2 per year will be captured by NETs by 2030, and 7.6 Gt CO_2 in 2050, which, the IEA admits, will require rapid and costly scaling from just 0.04 Gt CO_2 captured today. Hence, even under optimistic assumptions, counterbalancing only hard-to-abate emissions with NETs will be very challenging. Therefore, Ho's point quoted above applies to NETs in general: a total phase-out of *not*-hard-to-abate emissions (i.e. at least two thirds of emissions) is required, thus showing that urgent and ambitious mitigation is necessary even under optimistic assumptions regarding the potential of NETs.

But there is more. The residual hard-to-abate emissions and the figures cited in the previous paragraph do not include historical legacy emissions which continue to impact the climate (Buck et al. 2023, p. 355). If NETs are used to counterbalance residual emissions, its capacity is not available for the removal of legacy emissions or for coping with overshoot (Buck et al. 2023, p. 355). Hence, we may only be able to cover the *most*-difficult-to-abate emissions if we also want to tackle legacy emissions with NETs, implying that the majority of hard-to-abate emissions will have to be reduced by traditional mitigation strategies *as well*.

In addition to the limitations at the "capture" or "removal" side, the "storage" side presents major challenges and uncertainties as well. As argued above, BECCS has stringent sustainability constraints. Moreover, geological storage includes leakage risks, storage inefficiencies, high energy requirements, economic costs, chemical waste, and adverse impacts on biodiversity and the natural environment (Fagorite et al., 2022). I have no space here to discuss these problems into detail, but it should be clear that carbon storage poses significant challenges, 'while emissions reductions have *permanent impacts* on atmospheric concentrations' (McLaren et al., 2019, p. 2, original emphasis).

From a techno-optimist perspective, further developments of NETs could be expected to resolve many of these practical challenges. However, this would face the moral objection of risk transfer. First, it seems inconsistent to be sceptical about the potential of mitigation technologies (which is the basic argument in favour of NETs), while being overly optimistic about the potential of NETs. Second, even if we assume that solutions for the problems of NETs could be found in the future, deferring ambitious mitigation inevitably shifts the burden of large-scale NET deployment to people in the future. Third, if we do not invest in ambitious mitigation now and rather rely on NETs – *in casu* BECCS – we may jeopardize food security, which particularly poses risks to people in poverty. Even more profoundly, adopting the techno-optimist perspective implies that we gamble that future advances will resolve feasibility, scalability and storage issues (Anderson & Peters, 2016, p. 181; Shue, 2017a, p. 208), but we cannot be certain today that these problems will effectively be overcome or when. Crucially, the risk inherent to the gamble will not be borne by those who make the decision to rely on NETs today, but by people in the future who have no say in today's policy decisions and who may suffer grave losses (Shue, 2017a, p. 208). Hence, overly relying on the future development of NETs unavoidably transfers risks

[7] Buck and colleagues (2023, 351–352) admit that this is an imprecise estimate; I use it here only to indicate the magnitude of the challenge for NETs.

from today's affluent and polluting people (who save themselves the effort of reducing emissions) to poor, vulnerable and future people (who will bear the risks involved in the deployment of NETs as well as the risk that NETs may be insufficient to tackle climate change).

In sum, 'the ambition of actual mitigation now ought not to be reduced on the basis of reliance on assumed later negative emissions' (Shue, 2018, p. 7). NETs will play a role in climate policy, but they should be reserved for removing legacy emissions and the most-difficult-to-abate emissions only, and not be wasted on the large majority of emissions (which we could prevent today by mitigation).

2.3 Solar Radiation Management (SRM)

SRM or solar geoengineering is much-debated in the climate change literature. A number of methods qualify as SRM, such as marine cloud brightening, constructing a space sunshade or mirror, thinning of high-altitude cirrus clouds, and enhancing the reflective capacity (albedo) of the Earth's surface. My discussion will focus on the most prominent SRM method, namely stratospheric aerosol injection (SAI), whereby reflective aerosols would be introduced into the stratosphere to increase the reflection of incoming sunlight.

While SRM has been under a de facto moratorium, Switzerland, Monaco, and Guinea (co-sponsored by Georgia and Israel) have put forward a resolution to the United Nations Environment Assembly in February 2024 to establish an expert group under UN auspices to coordinate research regarding SRM (Watts, 2024). Relatedly, in a controversial report, the United Nations Environmental Programme (UNEP, 2023) states that the possibility that SRM may alleviate climate change impacts has led to advocacy for research into SRM as supplementary to mitigation and adaptation. The report concludes that 'there is a need for equitable, transparent and inclusive discussions about the science of SRM and related governance issues' (UNEP, 2023, p. 5). While this does not appear controversial, critics argue that the calls for an expert group and for more discussion may undermine the current de-facto ban on SRM and other forms of geoengineering *as well as* our commitment to urgent and ambitious mitigation (Watts, 2024).

Recently, the UK's Advanced Research and Invention Agency (ARIA. 2025) has launched its *Exploring Climate Cooling* programme, with funding of £56.8 m to support research into SRM and other geoengineering methods. Besides technical research (including real-world experiments), the research programme includes the exploration of crucial governance and ethical dimensions (ARIA, 2025). While ARIA (2025) does acknowledge that there is no substitute for decarbonisation, the justification for the investments is that 'our current warming trajectory already makes a number of tipping points distinctly possible over the next century,' but that there is a knowledge gap regarding approaches that could reduce temperatures globally or regionally over shorter timescales if faced with such climate tipping point. In a scathing comment, Hulme (2025) criticises the UK Government for 'leading the world down the "slippery slope" towards eventual dangerous large-scale deployment of solar engineering [SRM] technologies.'

I first want to note the virtual consensus in the scholarly debate that SRM cannot substitute for ambitious mitigation. Keith (2013, p. 128), a prominent proponent of SRM, emphasises that 'whether or not we deploy geoengineering, we must still eventually decarbonize our energy system to reduce long-run climate risks along with the direct impacts of ocean acidification.' It is also worth noting that the scholarly debate focuses on whether SRM *research* should be allowed and under which conditions.[8] Virtually no academic scholar advocates for SRM *deployment* at this time. Those who draw a clear line between research and deployment will object that the "slippery slope" argument against both the UNEP report and the UK's investment in SRM research mentioned above blurs this distinction, but others (such as Parson & Ernst, 2013, p. 326) argue that the distinction is blurry to begin with.

I will return to SRM research – and climate change research in general – in Sect. 3. In this section, I want to focus on the main reasons why SRM cannot substitute for decarbonisation, which in my view establish a strong case for avoiding the deployment of SRM, and if full avoidance is not possible, minimise our reliance on it as a fallback. This can only be achieved by urgent and ambitious emissions reductions.

Let us start with the objection that without significant decarbonisation, SRM would have to be maintained indefinitely to avoid global warming, which poses a significant long-term governance problem: 'the expectation that humankind would be able to continuously maintain a geoengineering effort at the requited level for this length of time is questionable, to say the least' (Jones et al., 2013, p. 9743–9744). SRM may be halted suddenly – the so-called "termination shock" – due to terrorism, economic collapse, international conflict, or natural disasters resulting in rapid and substantial increase in global temperatures (Irvine et al., 2016, p. 827; Jones et al., 2013, 6751; Parson & Ernst, 2013, p. 319; Trisos et al., 2018, p. 475). Parker and Irvine (2018) find that this is a real threat, but that policies could be put in place to increase resilience against termination drivers. Yet the global climate regime is weak, so the required policies to increase resilience are likely to suffer from (geo)political inertia. Hence, we cannot be certain that these policies will be implemented or complied with. More fundamentally, even if a termination shock can be avoided, without reducing emissions and atmospheric concentrations of greenhouse gases, present-day decision-makers are still committing future generations to maintaining SRM indefinitely (Svoboda, 2017, p. 50). Hence, in view of all the uncertainties, risks, costs, and burden-shifting, deploying SRM results in an intergenerational injustice.

The second objection states that SRM without ambitious decarbonisation results in biogeochemical problems caused by the accumulation of greenhouse gases in the atmosphere, including ocean acidification (and its effects on marine life and marine photosynthesis), negative effects on human health (including respiratory illnesses and cancer) and the negative effects of acid rain (such as decreased plant growth and productivity, increased soil acidification, and disturbance of the balance of microbial activities) (Keith, 2013, p. 100; Lauvset et al., 2017; Naiyer & Abbas, 2022; Prakash et al., 2023; Shi et al., 2021). To nuance this objection, Keith and colleagues (2017)

[8] See, for example, Gardiner (2011, Chap. 10; 2017); Horton et al. (2018); Horton and Keith (2016); Keith (2013); Parson and Ernst (2013); the essays in the collection edited by Preston (2012); and Svoboda (2017).

argue that SRM will also reduce the negative effects carbon burden due to carbon-cycle feedback, reduced permafrost melting, and reduced energy-sector emissions. However, even they find that 'solar geoengineering cannot substitute for cutting emissions,' because the carbon benefits amount to only 12–26% of total twenty-first century emissions (Keith et al., 2017, p. 618). Hence, although SRM may reduce or halt global warming, the detrimental impacts of the unabated accumulation of greenhouse gases in the atmosphere will exacerbate without urgent and ambitious decarbonisation.

In addition to these indirect effects, there may also be negative impacts resulting *directly* from SRM deployment, although there are still many uncertainties involved. SRM may cause unintended climatic changes, seasonal shifts and disruptions to weather patterns. It will likely have an impact on precipitation patterns, such as a disruption of the Indian Summer Monsoon (Krishnamohan & Bala, 2022) and a significant decrease in the West-African Monsoon (Da-Allada et al., 2020). Procter and colleagues (2018) find that the scattering sunlight caused by SRM will negatively impact the yield of crops such as maize, soy, rice and wheat, and that these damages are roughly equal in magnitude to benefits from the resulting cooling. SRM could also have a substantial impact on the meteorological variables (such as the diffusion of solar radiation, impacts on cloud cover and precipitation, and nitrogen availability) significant in the generation of solar energy, wind energy, hydropower and bioenergy (Kumler et al., 2025, p. 6–8). There would also be a complex interaction between SAI and stratospheric ozone chemistry (Irvine et al., 2016, p. 823). While large uncertainties remain, a precautionary approach would dictate that these and other effects of SRM cannot be underestimated.

Of major importance is that these adverse effects will mainly affect poor, vulnerable and future people, as well as nonhuman nature, who are unable to represent themselves (see also Gardiner, 2017). First, some of the same people that are most vulnerable to the effects of climate change also appear to be the most vulnerable to the potential adverse effects of SRM (Biermann et al., 2022, p. 3), because these people are dependent on the climate for their livelihoods and have the least capacity to cope with or adapt to changing temperatures, precipitation patterns or the effects of acid rain and ocean acidification. Horton and Keith (2016, p. 86, original emphasis) turn this argument around and argue that 'while it is true that SRM may *hurt* the developing world disproportionately, it is equally true that SRM may *help* the developing world disproportionately, at least in the near term.' This is at least to some extent belied, though, by Keith's (2013, p. 114) own argument that *gradually* ramping up SRM makes the most sense because most impacts depend more strongly on the rate than on the absolute amount of climate change. Even if SRM would deliver on these promises (which is uncertain), this means that the benefits of SRM in terms of reduced or averted climate impacts will only manifest gradually as well. More pertinently, the poor and vulnerable people are the least politically powerful in the international climate negotiations and so do not have a say in balancing the risks and potential benefits of SRM which mainly affect *them*.[9] The development

[9] One could object that a country or other agent in the developing world could decide to deploy SRM unilaterally to avoid harms resulting from climate change. However, Gardiner (2013) compellingly criti-

and deployment of SRM may exacerbate maldistributions of power, and raises questions of paternalism and imperialism vis-à-vis the global poor as well as Indigenous peoples (Hourdequin, 2018; Whyte, 2012).

Second, Fragnière and Gardiner (2016, p. 27) argue that SRM brings with it the threat of 'parochial forms of geoengineering, such as short-term geoengineering "fixes" which defer the worst impacts of climate change beyond the lifetimes of the current generation […], but at the cost of making matters much worse for future people.' To avoid this scenario, future people would have to continually increase SRM, increasing its risks and negative impacts, and eventually resulting in disastrous consequences (Keith, 2013, p. 43). Hence, engaging in SRM without simultaneous sustained reduction of emissions would impose a dilemma on future people, who will have had no say in today's decision-making process leading to it. According to Ott (2012, p. 41), imposing this dilemma on future people is repugnant, because other viable courses of action (that is, emissions reductions) are available (Ott, 2012, p. 41).

In addition, there are still large uncertainties regarding the effectiveness of different SRM methods, which means that there is still a risk that SRM will not deliver on its promise. Parallel to the case of NETs, a techno-optimist would object here that further research and technological development could be expected to resolve many of the uncertainties and risks involved in the deployment of SRM. However, this presents a gamble. The risks of this gamble will be borne by future people, whereas the present decision-makers only reap the benefits because they do not have to ramp up ambitions regarding decarbonisation.

Finally, non-human nature will potentially suffer significantly from the adverse effects of SRM. Increased ocean acidification and acid rain will have detrimental impacts on aquatic and terrestrial life. Although there may also be some beneficial effects of SRM on biodiversity (such as increased efficiency in photosynthesis due to diffuse radiation), these will likely be outweighed by the extinction of species that are less able to adapt to seasonal shifts, disruptions in weather and precipitation patterns, and changed solar radiation (Dagon & Schrag, 2019; Trisos et al., 2018).

In sum, although SRM should preferably be avoided, but we may need it as a fallback in worst-case scenarios – as suggested by Callies and Moellendorf (2021, p. 141–144). Nonetheless, this does not imply that we can increase our reliance on it in order to reduce our commitment to urgent and ambitious emissions reductions. If we cannot fully avoid the deployment of SRM, we should still strive to keep its role as limited as possible, because the less SRM we need to deploy, the lower the potential harms and risks; harms and risks that would befall poor, vulnerable, and future people, as well as nonhuman nature, rather than today's affluent and polluting decision-makers. This again calls for urgent and ambitious emissions reductions.

cises this "lesser evil" argument which refers to the plight of vulnerable people to justify the pursuit of a geoengineering agenda. Second, unilateral deployment of SRM risks the termination shock, which, as argued above, can only be avoided by substantial policies which require international agreement and collaboration.

3 The Moral Hazard Argument re-examined

In a recent paper, Callies and Moellendorf (2021) conclude that an emissions-reductions-only policy will not meet their criteria of (i) avoiding catastrophic climate change, while (ii) respecting the right to sustainable development. They argue that the optimal climate policy combines traditional mitigation with NETs, and SRM as a fallback. In principle, I agree with this conclusion. Yet, rather than criticising an emissions-reductions-only policy, I believe it would be more pertinent to focus on how we can minimise our reliance on the supplementary interventions. As argued in the previous section, for both practical and moral reasons, the less we depend on the supplementary climate interventions, the better. This turns around the debate: rather than justifying the supplementary measures, the goal should be to determine how to limit their necessity.

My concern is that justifying reliance on adaptation, NETs and/or SRM on the premise that mitigation will fail, will normalise them, increase reliance on them, and consequently reduce our commitment to urgent and ambitious emissions reductions.[10] This is a version of the *moral hazard argument* and holds a self-fulfilling prophecy: justifying (over-)reliance on the supplementary climate interventions on the assumption that emissions reductions will not suffice may further undermine our commitment to mitigation in a defeatist fashion, which, in turn, increases the extent to which the supplementary interventions become necessary (see also Gardiner, 2011, p. 356). This is especially problematic since the premise – the failure of mitigation due to political inertia – is not a neutral fact. Taking it uncritically as a given would obscure 'a vital moral feature of the situation: the potential crisis is to be brought about by *our* (the current generation's) *failure* to pursue better climate policies' (Gardiner, 2011, p. 360, original emphasis).[11]

Callies and Moellendorf (2021, p. 139–140) do not find the worry that the supplementary interventions may establish a moral hazard decisive because they are sceptical that ramping up an emissions-reductions-only policy can work in view of its geophysical limits and the social and political complexities involved anyway. Moellendorf (2022, p. 158) adds that 'the main barrier to limiting warming to within the goals of the Paris Agreement has to do with context [i.e. the geo-physical limits and political hurdles], not with motivation,' *de facto* dismissing the moral hazard argument. I disagree with this view for several reasons, and analysing them will advance the debate on the moral hazard argument in general.

(i) Let us first look at the factors that according Callies and Moellendorf lead to the failure of an emissions-only policy more into detail. With the *geophysical limits*, they in first instance refer to the existing concentration of greenhouse gases in the atmo-

[10] Winsberg (2021, 1123, original emphasis), for instance, assumes that climate pessimism – that is, 'the claim humans are nearly certain not to achieve sufficient climate change mitigation such that the damage caused by climate change is significantly greater than the sum total of the *clearly foreseeable* harmful side effects of SAI' – has become nearly unassailable. While I do not entirely disagree, it is us, today, who can still influence whether – or rather, to what extent – the premise of the claim comes true. In other words, we should refute the assertion that this claim has become *nearly unassailable*, because it undermines our commitment to decarbonisation, and this would make the claim a self-fulfilling prophecy.

[11] For further discussion of this, see Fragnière and Gardiner (2016, 25); Gardiner (2013); and Keith (2013).

sphere, already causing significant global warming (Callies & Moellendorf, 2021, p. 136). This is indeed reason enough to consider supplementing mitigation with adaptation and NETs. However, as argued above, adaptation cannot be successful without ambitious mitigation, and NETs should be reserved precisely for tackling these legacy emissions (together with the most-difficult-to-abate emissions) but cannot be used to counterbalance the large majority of emissions. Nonetheless, even though Callies and Moellendorf (2021, p. 138–141) recognise that NETs must be accompanied by ambitious decarbonisation, they advocate 'widespread deployment' and, in contrast to mitigation, do not discuss the significant geophysical constraints of NETs which I have discussed in Sect. 2.2 above. Since an overestimation of the potential of NETs is likely to result in mitigation deterrence (von Rothkirch et al., 2024, p. 7–8), the substantial constraints of NETs should rather be central to the debate in order to ascribe them a correct (limited) role in climate change policy.

In addition to the geophysical limits, Callies and Moellendorf (2021, p. 135–138) discuss the *political barriers* to effective emissions reductions. These barriers include the collective action problems of international negotiations; the uncertainty about the most effective instruments to implement an agreement about decarbonisation; the complexities involved in coordinating the actions of multiple agents; the capriciousness of democratic politics; the serious problems for international cooperation legislative reversals pose; and resistance against the energy transition. These political hurdles indeed pose significant impediments to ambitious emissions reductions. Nonetheless, taking them as a given is problematic, because this contributes to the self-fulfilling prophecy above: assuming that mitigation will fail due to political impediments will only increase political inertia, rather than addressing it.

It should be noted that similar concerns mar the supplementary climate interventions as well (see also Gardiner, 2011, p. 364). It would lead me too far to discuss all the likely political hurdles into detail but let me illustrate them for each of the supplementary climate interventions.

First, even though *adaptation* can in theory be done unilaterally, international agreements about financing are necessary, because developing countries – which are, in general, the most vulnerable to the impacts of climate change – are unable to finance these investments. As exemplified by the current gap between the costs/finance needs of adaptation in the international finance flows (see Sect. 2.1 above), adaptation involves collective action problems that are similar to those impeding the international negotiations about emissions reductions.

Second, due to their financial costs, *NETs* are most likely to be developed by developed countries, hence their deployment may be used to strengthen the geopolitical dominance of the developed countries. BECCS relies to a large extent on land in the developing world, where it will compete with food production, but also biodiversity conservation and other sustainable development goals. For DACCS, the sheer number of facilities needed will require cooperation between many countries. Moreover, the deployment of NETs will benefit all nations, but it is in every nation's financial self-interest to free-ride and let others shoulder the costs. In sum, just like mitigation, the deployment of NETs is likely to be plagued by problems of international coordination, collective action and geopolitics.

Third, SRM appears administratively simple and seemingly deployable without international agreement. However, Gardiner (2011, p. 348) calls this claim politically naïve because major countries are unlikely to stand aside while a single corporation or country modifies the climate. Governance is widely regarded as one of the greatest – if not *the* greatest – challenge facing geoengineering (Horton et al., 2018, 5–6; Keith, 2013, p. 183) posing multiple acute and novel problems for international governance and its established norms (Hourdequin, 2018, p. 283; Parson & Ernst, 2013, p. 330–331). For instance, geographical distribution of SRM could significantly increase resilience against potential termination shocks (Parker & Irvine, 2018; see Sect. 2.3 above), but this introduces the very political hurdles (such as complexities of coordination, collective action, and geopolitics) Callies and Moellendorf discuss regarding mitigation. Svoboda (2017, p. 50) argues that an SRM policy without a viable exit strategy may be morally impermissible, but doubts the political feasibility of multilateral agreement on the parameters of such an exit strategy. Moreover, SRM poses major risks for developing countries, yet those countries able to develop it are unlikely to share control with the most vulnerable countries (Biermann et al., 2022, p. 3). SRM would demand global inclusive and just decision-making – something Biermann and colleagues (2022, p. 3) deem impossible under the current international political system. In sum, the root causes for the political inertia on mitigation are likely to constrain SRM governance as well (Fragnière & Gardiner, 2016, p. 28; Gardiner, 2011, p. 363; 2013, p. 30).

We cannot take the political hurdles to emissions reductions as an incontrovertible fact, because this would contribute to the moral hazard. Moreover, they exist regarding the supplementary climate interventions as well. Hence, the argument that the moral failure of mitigation due to political inertia justifies shifting our attention to the supplementary interventions is incoherent. Rather than taking the political hurdles to mitigation as a given, academic and political participants at the debate have a duty to find ways to overcome them. In other words, the *roots* of the political inertia regarding climate change must be urgently addressed.

(ii) In contrast to Callies and Moellendorf's scepticism regarding the moral hazard argument, I would argue that reliance on supplementary climate interventions *further undermines the already weak ambitions* regarding emissions reductions (see also Parson & Ernst, 2013, p. 319). Here it is useful to distinguish between the moral hazard as an individual, psychological effect or a structural process.

First, the moral hazard can be interpreted as a *psychological effect on individuals* whose commitment to mitigation may be weakened if they were to see the supplementary measures as a convenient substitute for more difficult emissions reductions. Empirical research indicates that the public seems much less concerned about the moral hazard than often assumed (Bellamy et al. 2022, p. 8). Studies questioning whether informing participants about NETs and SRM would result in mitigation deterrence have had inconclusive or null results (Bellamy, 2022; Carton et al., 2023; Hart et al., 2022; Merk et al., 2016; Schoenegger & Mintz-Woo, 2024). Bellamy and colleagues (2016) found that DACCS overall scored moderately in citizens' appraisal, but poorly on the feasibility and social criteria. SAI performed very poorly against environmental criteria; poorly against safety, ethical and social criteria; moderately against feasibility and economic criteria; and highly against efficacy criteria.

Voluntary low carbon living and offshore wind energy, in contrast, performed much better. In fact, there is evidence indicating that informing participants about NETs and/or SRM *increases* their commitment to mitigation (Merk et al., 2016; Schoenegger & Mintz-Woo, 2024).

However, it should be noted that other factors – such as demographic and socio-economic factors (age, gender, social class), political ideology, and trust in government or science – turn out to be more significant in determining commitment to ambitious mitigation (Bellamy et al. 2022; Hart et al., 2022; Schoenegger & Mintz-Woo, 2024). Moreover, and in my view crucially, there seems to be consensus among researchers that their results depend on the specific messages, information and framings given to participants (Hart et al., 2022; Merk et al., 2016; Merk & Wagner, 2024). Merk and colleagues (2016) find clear evidence for this: subjects who perceive SAI to be ineffective do not change their behavior, and the increased mitigation behavior of others is attributed to the perception of SAI as a threat (thus a lack of acceptance of the technology). Hart et al. (2022, p. 9) included language about NETs being 'still mostly unproven' in their information of participants which may explain the null effect. I will return to the issue that framings of and information regarding the supplementary interventions may influence individuals' commitment to ambitious mitigation below.

In contrast to the interpretation as an individual psychological effect, the moral hazard can be seen as a *structural process* generating institutional, political and economic values and decisions that delay mitigation. As discussed in Sect. 2, there is at least anecdotal evidence for the erosion of our commitment to urgent and ambitious emissions reductions due to reliance on the supplementary measures on the structural level, viz. in public discourse and climate policy. This evidence was most significant in the case of NETs: the failure to distinguish transparently between emissions reductions and NET targets already undermine effective climate policy in which mitigation should play a central role. According to Carton (2019, p. 759), the concept of NETs itself already has concrete implications because it fosters the notion that ambitious climate targets are still within reach, that current policy commitments are sufficient, and that we are taking appropriate action.

I would argue that the main origins for the moral hazard on the structural level, generating collective decisions that delay mitigation, can be found in the liberal-capitalist worldview. This is the dominant social paradigm, deeply entrenched in Western political ideologies, but increasingly dominant around the world (Peeters et al., 2015, p. 100; Shafer, 2006, p. 125).[12] Central to his worldview is a belief in unlimited economic growth associated with vested economic and political interests in the status quo based on fossil fuels. Additional core values are a commitment to limited government, support of free enterprise and private property rights, and faith in the efficacy of science and technology (Dunlap & Van Liere, 1984, p. 1015). The individual freedoms to accumulate wealth and to consume – the interpretation of happiness central

[12] Arguably, the liberal capitalist worldview is adopted across the political spectrum in developed countries, excluding only the radical left. Even centrum and centrum-left parties have strong faith in the efficacy of science and technology, and believe (to a varying degrees) *inter alia* in unlimited economic growth and future abundance.

in the liberal-capitalist worldview – have been conferred an unassailable status in view of their role in maintaining economic growth (Peeters et al., 2015, p. 101-102).

The demand for ambitious and urgent reductions of emissions conflicts with this dominant social paradigm on multiple levels. Rapid decarbonization will result in the devaluation of fossil fuel assets, which upsets the economic status quo as well as the vested interests of industries and elites. It would also run counter to the central commitment to limited government and deregulation of the economy. On an individual level, urgent and ambitious reductions of emissions profoundly unsettle the presumed inviolable status of materialistic freedoms, the preference for a consumerist lifestyle, materialistic habits and cherished practices such as the consumption of animal products and the profligate consumption of energy (Peeters et al. 2015, chapter 4. 2019). Those individuals, industrial actors and institutional actors alike, who favour the continuation of the liberal-capitalist worldview will resist ambitious mitigation (see also Gardiner, 2011, p. 30). Indeed, structural accounts of the moral hazard highlight how the promise of future NETs in particular 'fulfil an important function for incumbent actors,' reducing the (perceived) negative economic effects of mitigation while seemingly alleviating demands for effective climate action (Carton and colleagues, 2023, 9).

Moellendorf (2022, p. 158–159) explicitly discounts the problem of motivation as a barrier to limiting global warming and rather attributes it to geophysical limits and the problems of political economy. Yet, we should acknowledge that in addition to geopolitics, the political hurdles impeding mitigation result from the liberal-capitalist worldview: measures to reduce emissions unsettle vested interests in the status quo, so it is not difficult to see the reluctance of the political elites to accept them. In contrast, the supplementary climate interventions are much easier to accept because they allow the continuation of consumerist lifestyles while safeguarding existing production processes on the basis of fossil fuels, at least for the time being. Reliance on the supplementary interventions, and NETs and SRM in particular, fits seamlessly with the central techno-optimist view that science and technology induce progress and solve any social and environmental problems caused by the pursuit of liberal-capitalist values (Kilbourne et al., 2002, p. 197; Peeters et al., 2015, p. 101; Polonsky et al., 2014). Regarding NETs, for example, Anderson and Peters (2016, p. 183) argue that their promise 'is more politically appealing than the prospect of developing policies to deliver rapid and deep mitigation now.' Hence, *pace* Moellendorf, I believe that the moral hazard concern is *fundamentally* a matter of motivation, viz. the reluctance to accept the negative impact of decarbonisation on the vested interests in a fossil-fuel economy and the pursuit of materialistic lifestyles, which are rooted in the hegemonic liberal-capitalist worldview.

A compounding factor lies in what Gardiner (2011, Chap. 9) has called *moral corruption*. Whereas decarbonisation unsettles the values and vested interests inherent to the liberal-capitalist worldview, the supplementary climate interventions allow us to "pass the buck," by transferring risks to poor and vulnerable people in the present and future, and to non-human nature. Because we are reluctant to face up to moral criticism for this, we are likely to be attracted to weak or deceptive arguments that subvert our understanding (Gardiner, 2011, p. 302).

We have seen that the results of the empirical studies researching individual commitments to ambitious mitigation are highly dependent on the specific messages, information and framings with which NETs and SRM are presented. It is unsurprising that individual participants to these studies do not reduce their commitments to mitigation when they are *well-informed* about the constraints and risks of the supplementary interventions. However, I would submit that "being well-informed" is a rather high standard for the wider public discourse on climate change. The general lack of knowledge could be exploited by economically and politically powerful actors to protect their interests. Indeed, Markusson and colleagues (2018, p. 7) argue that a neoliberal political regime benefits from obscuring the poor substitutability between NETs and mitigation, which can increase the likelihood of mitigation deterrence. Even proponents of (conducting research into) SRM worry that those with vested interests in the fossil-fuel economy may use the prospect of SRM to weaken mitigation efforts (Horton et al., 2018, p. 12; Horton & Keith, 2016, p. 87; Keith, 2013, p. 179). I indeed fear that the economically and politically powerful are tempted to misrepresent the supplementary interventions by downplaying or obscuring their constraints and risks in order to portray them as attractive, easy techno-fixes.[13] The public may be willing to go along with this, out of ignorance combined with a reluctance to accept ambitious emissions reductions, the requirements of which profoundly challenge their materialistic values and freedoms as well. Hence, I argue that in order to increase mitigation deterrence (which would serve their interests), the economically and politically powerful in fact *manufacture* or *artificially augment* the moral hazard by misleading the wider public. In my view, this increases the salience of the interpretation of the moral hazard as a structural process.

(iii) I want to turn briefly to the questions whether research into the supplementary interventions on its own risks contributing to the moral hazard and whether this constitute sufficient reason to halt such research.[14] If climate policy should consist of emissions reductions as the primary strategy, combined with adaptation to address the impacts of the warming we are already committed to, NETs to cover the most-difficult-to-abate and legacy emissions, and SRM as a fallback, then further research regarding the supplementary interventions seems crucial.[15] However, we should

[13] Winsberg (2021, 1128) asserts that 'it is hard to see how an option "widely acknowledged to be an inferior, problematic, and at best temporary" [that is, SRM] could be seen as a "perfect excuse" to avoid real climate action.' "Being well-informed" is again the crux here: those who are informed about the constraints and risk of SRM will acknowledge it as an inferior solution and can be expected to keep their mitigation commitments high. However, the wider public is insufficiently informed on these issues, and this lack of knowledge may be exploited by the economically and politically powerful.

[14] This is most prominently debated regarding SRM research (see, for example, Gardiner (2011, Chap. 10); Hourdequin (2018); Horton and Keith (2016); Horton and colleagues (2018); Keith (2013); Parson and Ernst (2013); and Winsberg (2021). Addressing all the elements raised in this debate unfortunately falls beyond the scope of this paper; I will focus on the most relevant issues for my argument.

[15] Proponents of SRM research often advocate it on the basis that we owe it to future people to do research, so that *if* we need it, we have at least developed the knowledge to do so. Gardiner (2011, Chap. 10) comprehensively criticises this "arms the future" argument. I don't have space to discuss this critique into detail, but I agree with Gardiner that enhancing knowledge regarding SRM (and adaptation and NETs) is insufficient compensation for the moral failure to reduce emissions. In addition, there seems to be consensus in the debate that governance of SRM research is at least as important as conducting the scientific research itself.

proceed with caution in order to ensure that this research does not lead to further mitigation deterrence. A first concern that should be taken seriously is the fact that there are limited resources for research, which implies that research on the supplementary interventions is likely to displace resources that could be used on mitigation research (Gardiner, 2011, p. 350; Winsberg, 2021, p. 1114). I do not believe that this provides a strong moral argument against research into the supplementary interventions. Rather, climate change research overall deserves far more funding; the lion's share should be reserved for research and development of mitigation options, but the supplementary interventions (and especially adaptation) should receive an adequate share as well. This is an uncontroversial as well as naïve claim, but it again refers to the fact that the failure to reduce emissions (to which the lack of sufficient funding has contributed) has created the moral context in which decisions regarding climate change – including research – currently are made.

The second concern regarding research into the supplementary interventions is that it may develop institutional momentum which will make increased reliance on them more likely. This is especially argued in the context of SRM (see for example Gardiner, 2011, p. 351; Keith, 2013, p. 178). Strong governance regarding climate change research is therefore necessary. Hourdequin (2018) argues that participatory parity and recognition should be central to the governance of SRM research in order to take seriously concerns about paternalism, parochialism and expertise imperialism. I believe that these recommendations should be broadened to climate change research in general, not only to attend to Hourdequin's important concerns regarding participatory parity and recognition, but also to safeguard against institutional momentum leading to mitigation deterrence.

Third, it has been argued that research will quickly shed light on the constraints of and risks involved in the supplementary interventions (Keith, 2013, p. 121) and that it will promote ethical norms and best practices in research (Winsberg, 2021, p. 1127). Yet, what worries me here is the possibility that research will rather be misappropriated by the politically and economically powerful. Winsberg (2021, p. 1119) rightly notes that 'all scientific research has a non-trivial probability of being misinterpreted by decision makers in one direction of the other.' In line with my argument above, people with vested interests in the continuation of the liberal-capitalist worldview may corrupt or misrepresent the results of research on the supplementary interventions to impede ambitious decarbonisation. I agree with Morrow (2014, p. 10) that in the short term at least, researchers have a significant responsibility to prevent such misappropriation by being mindful of how they convey information to various audiences as well by engaging with the public and policy-makers in nuanced, transparent and clear ways. In addition, researchers should be more outspoken in the public debate, especially to refute false beliefs and correct misrepresentations of research results.

The final concern regarding research I want to briefly discuss here is that even though I remain an advocate for research, we should also remain aware of the fact that optimism about scientific progress is closely related to techno-optimism. If the social and environmental problems caused by pursuing the values of liberal-capitalist worldview are recast as problems to which scientific research will find a solution, their root causes – the tenets central to the liberal-capitalist worldview such as the

pursuit of materialistic freedoms and vested interests in the fossil-fuel based status quo – remain unchallenged. We should therefore remain critical about the values underlying climate change research, its objectives, and how its results are used.

(iv) Finally, we should not forget what is at stake. In the logic of the moral hazard argument, the incentive to engage in hazardous behaviour is higher when the risks are borne by others. As we have seen in the previous section, a shift from ambitious emissions reductions to adaptation, NETs and SRM comes with significant transfers of risks. On the one hand, the risks associated with *mitigation* are the costs and efforts involved in ambitious emissions reductions, which will mainly and at least at first be borne by today's affluent and polluting people (see below). On the other hand, there are particular risks associated with each of *the supplementary strategies*. Moreover, if our gamble fails – if the supplementary climate interventions fail to deliver on their promise in a scenario where we have chosen not to mitigate – then this will result in significant costs and damages resulting from unabated impacts of climate change. These costs and risks will disproportionately fall on poor, vulnerable and future people, as well as non-human nature. Paraphrasing Shue (2017a, p. 208; 2018, p. 3) and Gardiner (2013, p. 30), what is especially problematic in this "buckpassing" resulting from reducing our commitment to ambitious mitigation and relying more on the supplementary interventions is that affluent and polluting people of the present may gain *something relatively inconsequential* – a profligate lifestyle and the pursuit of vested interests in the fossil-fuel based economy, or, in other words, the continuation of the liberal-capitalist worldview – by imposing *severe risks of grave losses* on poor, vulnerable and future people, as well as non-human nature.

This transfer of risk is especially egregious due to fact that those who benefit from it (today's affluent and polluting people) are the most responsible for climate change and wield the most power in international decision-making, whereas those who will instead bear most of the risks (poor, vulnerable, and future people, as well as nonhuman nature) are least responsible for the causation of climate change, have little or no say, and are thus at the mercy of today's affluent and polluting people. Hence, the transfer of risk is an issue of distributive injustice compounded by striking participatory injustice.

In sum, a determined commitment to ambitious mitigation challenges the hegemonic liberal-capitalist worldview, whereas the supplementary climate interventions leave it largely unchallenged. This is a central motivating factor for today's economically and politically powerful to shift attention from ambitious mitigation to the supplementary climate interventions, which, due to the moral hazard logic, may bring about a self-fulfilling prophecy and result in increased mitigation deterrence. This comes at a serious moral cost, viz. the imposition of significant risks on vulnerable, poor, and future people, as well as nonhuman nature.

4 Mitigation re-examined

My argument in this paper would remain biased if I do not acknowledge the fact that mitigation could also lead to risk transfers. I will address this issue and argue that it is avoidable in the case of mitigation, whereas it is inherent to undue reliance on the

supplementary interventions. Subsequently, I will discuss the potential of emissions reduction strategies.

(i) It can be objected that the moral problem of risk transfers applies to the ambitious and urgent reduction of emissions I have been advocating. This danger can present itself in two main ways.

First, there may be mitigation strategies with morally problematic impacts. For instance, the Norwegian Human Rights Institution (NIM, 2024) has recently reported on how climate harms as well as climate solutions can negatively impact the Sámi people. Industrial developments such as wind and solar projects or the mining of minerals may result in violations of their human rights, *inter alia* through loss of access to the lands and waters they have traditionally used (NIM, 2024, p. 56). Such a negative impact on Sámi culture cannot be offset by the interests in climate solutions of society at large, especially because Article 27 of the International Covenant on Civil and Political Rights on the protection of minorities does not provide for limitations (NIM, 2024, p. 56–57). Consider, in addition, that some mitigation strategies can have a detrimental impact on the natural environment. For example, some countries are already applying to the UN for permits to explore deep-sea mining for materials needed in the energy transition (such as lithium, cobalt and graphite) in international waters (Ashford et al., 2024). However, there are significant concerns *inter alia* about potential direct harm to marine life, long-term species and ecosystem disruption, and possible impacts on fishing and food security of deep-sea mining (Ashford et al., 2024). Other examples of mitigation strategies with undesirable impacts include the problem that hydropower may result in the destruction of local communities and environment, or that wind farms may destroy the landscape (Schwenkenbecher & Breukner 2023, p. 365–368).

The transfer of risk embedded in these instances has a structure seemingly similar to the transfers of risk involved in moving to adaptation, NETs and/or SRM discussed above: the risks and negative impacts of dealing with climate change are transferred from affluent and polluting people to Indigenous peoples and to the natural environment, respectively. However, there is a significant difference. Whereas the transfer of risk is *inherent* to over-relying on the supplementary interventions (and consequently reducing our commitment to urgent and ambitious mitigation), the risks involved in certain mitigation strategies can in large part be avoided by choosing more appropriate strategies. Indeed, the NIM (2024, p. 57–58) recommends exploring alternative mitigation measures that would not interfere with Sámi rights, such as locating wind power development in other areas or the development of solar or offshore wind energy. In the case of deep-sea mining, the Word Resources Institute believes that mineral reserves on land would be sufficient to meet global needs, and that we rather should focus further development of battery technology and on responsibly scaling up mining and processing operations as well as mineral recycling (Ashford et al., 2024).

The second way in which a transfer of risk can materialise is that ambitious emissions reductions may result in slower development of the poorest countries due to reduced economic growth and by demanding them to forego development based on fossil fuels in favour of sustainable development, which may be slower and more expensive (Callies & Moellendorf, 2021, p. 134; Shue, 2017b, p. 468). Horton and

Keith (2016, p. 81–83) argue that concern for the poor is actually a major argument *in favour of* SRM. The costs of mitigation – such as increased energy costs – will be disproportionately borne by the poor in the near term, while the benefits will occur in the future and will be universal. SRM, in contrast, would likely provide net benefits in the near term that would help the poor most of all by preventing detrimental climate impacts (see also Keith, 2013, p. 165–168). Hence, the near-term benefits of SRM for the poor, they argue, will outweigh its costs in terms of risks.

However, Horton and Keith's calculus does not take into account a number of relevant factors. For one, there is deep uncertainty regarding the impacts of SRM (Svoboda, 2017, p. 8), which poses significant problems for cost-benefit analyses. In addition, the assumption that fossil fuels are or will remain less expensive than non-carbon energy is no longer valid. The International Renewable Energy Agency (IRENA, 2024, p. 16) reports that 81% of newly commissioned renewable power generation projects were cheaper than fossil fuel alternatives in 2023. Moreover, in contrast to fossil fuels, renewable energy options (such as solar panels) do not require large energy infrastructures and are thus are easier and cheaper to deploy in energy-poor or isolated communities with immediate benefits for these communities. On the basis of these factors, I doubt that a cost-benefit comparison between emissions reductions and SRM will turn out in favour of SRM.

Moreover, in addition to pointing out the salience of paternalism, parochialism and expertise imperialism in relation to SRM research and development, Hourdequin (2018, p. 279–280) criticises Horton and Keith's assumption that the costs of mitigation *necessarily* fall on the poor. If wealthy nations truly cared about the wellbeing of the poor, they should increase (funding for) emissions reductions.[16] In addition, phasing out global fossil fuel subsidies – which, according to the International Monetary Fund (IMF, 2025), amounted to $7 trillion or 7.1% of global GDP in 2022, reflecting undercharging for supply costs (18%) and externalisation of environmental costs and forgone consumption taxes (82%) – could free up resources to assist the poor and make renewable energy even more accessible. Hence, the often-cited objection that the costs of ambitious emissions reductions will disproportionately be borne by the poor can be debunked: affluent people can counteract this problem by contributing more substantially to development and poverty alleviation in addition to increasing emissions reductions efforts (see also Shue, 2017b, p. 468).[17]

The final counterargument is that many of the main mitigation options (such as energy efficiency, renewable energy, urban planning, and biodiversity conservation) can have multiple synergies with the Sustainable Development Goals (IPCC, 2022b, p. 1761–1762). Strategies with a high synergy potential should therefore be

[16] And if the wealthy care too little for the poor, Hourdequin (2018, 280) continues, Horton and Keith's assumption that SRM research and development will prioritise the interests of the poor also becomes questionable.

[17] Similar to the case of adaptation (see Sect. 2.1 above), the international finance flows to support the sustainable development of developing countries is currently vastly insufficient. The difference between financial support for adaptation and mitigation is that by relying on adaptation, the affluent force vulnerable people to adapt to climate change even if the financial support would be sufficient. In contrast, by supporting sustainable development, the affluent could be assisting the poor in realising their human rights in a sustainable way, and so this should be prioritised.

prioritised to reduce emissions *and* promote development. Moreover, further research should be conducted to enhance our understanding of the underlying mechanisms that can maximise synergies.

In sum, these counterarguments against the claim that ambitious emissions reductions will negatively impact development again demonstrate that the potential transfer of risks is not *inherent* to decarbonisation. The risks can be avoided by diverting resources to the poor and selecting the strategies that maximise synergies between mitigation and equity. I agree when Moellendorf (2022, p. 25) when he concludes that 'the moral of the story is that climate change mitigation is a pro-poor project.'

(ii) Another question concerns the potential for ambitious and urgent emissions reductions. Rather than focussing on the geophysical constraints limiting decarbonisation, I would argue that we should emphasise the large, accessible potential to reduce emissions that has yet remained untapped. Consider for example that mitigation options costing USD100 per tonne of CO_2 or less could reduce global emissions by half (relative to the 2019 level) by 2030, and half of this potential is made up by options costing even less than USD20 per tonne of CO_2 (IPCC, 2022b, p. 37–38). The mitigation options with the largest potential here are wind and solar energy, carbon sequestration in agriculture, and reduced conversion of forests and other ecosystems (IPCC, 2022b, p. 38). Together, these options can deliver a reduction of 16 Gigatonnes of CO_2. Additional options include ecosystem restoration, reducing demand for energy services in buildings, investing in fuel-efficient or electric vehicles, shifting to public transportation, fuel switching, and increasing efficiency in shipping and aviation (IPCC, 2022b, p. 38). Crucially, the technologies required for most of these mitigation options are already available; the uncertainties, risks or potential negative side-effects involved (if any) are well-known; and in most cases, there are significant potential synergies with sustainable development. Scaling up these mitigation options is therefore a mere political decision (see also Schwenkenbecher & Breukner, 2023). The sooner this scaling-up happens, the fewer legacy emissions are emitted, and risks or costs in the future (either because they result in climate damages or because they need to be counterbalanced by NETs or SRM) are reduced. In sum, our priority should be to deploy as urgently as possible the many and effective emissions reduction options with which we are already familiar.

Moreover, there is current research into more advanced technologies which have the potential to further reduce emissions in the near future, such as next-generation renewable energy, low-carbon building materials, energy grid innovations, and advances in agriculture. Again, the faster we can develop these technologies, the lower the future risks and costs related to legacy emissions that could have been avoided. Winsberg (2021, p. 1128) argues that some moral hazard arguments are grounded in a belief that emissions reductions could be 'right around the corner.' While I agree that the combined mitigation potentials of already available solutions and future technologies will be insufficient to climate change in its entirety, the defeatist view that mitigation has failed is not warranted either. The fact that we are *still* able to avert a large proportion of climate change by emissions reduction should rather motivate us to ramp up mitigation efforts.

As a further point, I should mention that until now I have focussed on technology-based mitigation options. In contrast to the supplementary interventions, technology-based mitigation challenges the vested interests in the fossil-fuel based economy that are inextricably related to the liberal-capitalist worldview. Nonetheless, a narrow focus on technology-based mitigation should be approached critically as well, because it does not challenge the liberal-capitalist view on a deeper level. It still allows the values of wealth accumulation and consumption central to the liberal-capitalist worldview to retain their unassailable status. This is consistent with the techno-optimist belief that science and technology will be able to solve all of the social and environmental problems caused by pursuing the values central to the liberal-capitalist worldview (Kilbourne et al., 2002; Peeters et al., 2015, p. 101).

To be clear, the potential of technological options to reduce emissions is huge, so they should be central to any climate policy. But we should acknowledge that there are also considerations that temper techno-optimism here. First, as already mentioned above, there may be risks or negative impacts that render certain technology-based mitigation options (such as deep-sea mining) undesirable. Moreover, even the most efficient technologies will have a residual impact on the environment. Finally, and most fundamentally, overreliance on technological solutions to reduce greenhouse gas emissions can lead to a moral hazard as well because it may erode our commitment to the non-technological emissions reductions (such as lifestyle changes) that, arguably, are vital too to reduce the remaining emissions.

It is therefore essential to go beyond technological solutions and to focus on consumption and population as well.[18] There are substantial bodies of literature regarding both, but I will focus on a few brief observations regarding the links with the liberal-capitalist worldview. First, addressing *consumption* goes to the heart of the liberal-capitalist worldview, because its interpretation of happiness in terms of materialistic and consumptive pursuits is called into question. A number of authors (*inter alia* Brown & Kasser, 2005; Jackson, 2009, 2021; Kasser, 2002; Soper, 2007, 2012) have drawn attention to the negative effects on wellbeing of pursuing materialistic values, and to the fact that the most important sources of life satisfaction (such as freedom, community involvement, personal growth, relationships and self-respect) are non-material in nature. On a societal level, this would justify pursuing an *a-growth* strategy which remains agnostic about economic growth, but rather focuses on promoting the factors that contribute to wellbeing, such as meaningful employment, equity and a stable climate (Van Den Bergh, 2017, 109–110).[19] Interest in these topics seems to have waned recently, but I think that further research would be useful, for example as to how to expedite the shift in focus from materialistic values to non-material sources of life satisfaction.

[18] The famous *IPAT equation* holds that environmental impact (I) is determined by population (P), affluence or consumption (A), and technological efficiency (T). Technological efficiency is commonly viewed as the mediator of the environmental impact caused by Population and Affluence. It should be noted that several other factors (such as trade, urbanization, culture, and institutions) play a cross-cutting role as well (Rosa & Dietz, 2012), but a more detailed analysis of these falls beyond the scope of this paper.

[19] Callies and Moellendorf (2021, 134–135) criticise *degrowth* for not being compatible with the right to promote sustainable development. I agree with this analysis regarding *degrowth*, but regrettably, they do not consider *a-growth* strategies.

Second, the *population* question is related to the liberal-capitalist worldview as well because population growth is an intrinsic contributor to economic growth.[20] Indeed, although environmental sustainability in the very long term will likely require lowering global population pressures, the declining birth rates to sub-replacement levels in advanced economies has been met with alarmism about a demographical 'collapse' and anxiety about the economic repercussions (UN Population Fund 2025). For example, in 2023, Japan's Prime Minister stated that 'Japan is standing on the verge of whether we can continue to function as a society. … Focussing attention on policies regarding children and child-rearing is an issue that cannot wait and cannot be postponed' (Kishida in Wright, 2023). Similarly, South Korea's fertility rate has been falling dramatically in the last few decades to currently the lowest in the world. This has been covered widely by the media as a 'demographic crisis,' and the Korean government promised to come up with 'extraordinary measures' to tackle it (McCurry, 2024). Many developed countries will soon face the challenge low fertility rates pose to their economies geared towards growth, and the main solution for it – viz. migration – is complicated by negative sentiments against it in many developed countries. Moreover, many of the factors leading to low fertility rates in for example South Korea and Japan (*inter alia* gender inequality and discrimination, rising living costs, and social norms regarding the family) (McCurry, 2024) are morally problematic. Whereas population ethics has mainly focussed on theoretical questions, there seems to be a gap when it comes to applied research into these issues on the intersection of ethics, demographics, economics and politics.

5 Conclusion

The main question for climate change, in my view, is not whether we will need adaptation, NETs and/or SRM to successfully tackle climate change, but rather how we can keep our reliance on adaptation as limited as possible (even though it is obvious that the current state of the climate already necessitates substantial deployment); keep NETs for covering the most-difficult-to-abate and legacy emissions; and avoid SRM (or, if full avoidance is not feasible, minimise our reliance on it as a fallback). I have argued that each of the supplementary interventions have constraints to their potential. Moreover, the more we rely on these supplementary climate interventions, the higher the risks transferred to poor, vulnerable and future people, as well as non-human nature. Table 1 summarises these arguments.

For these reasons, the challenge is to minimise our reliance on the supplementary climate measures through urgent and ambitious emissions reductions. However, the moral hazard problem, interpreted as a structural process influencing policy decisions and public discourse, poses a real danger to this: justifying the supplementary climate interventions on the premise that mitigation has failed or will fail, may in fact further

[20] Due to demographic momentum, the effects of lower fertility rates will come too late to contribute substantially to the reduction of emissions needed to mitigate climate change. Nonetheless, I strongly believe reducing population remains necessary to achieve sustainability in the very long term. I do not believe this claim to be controversial, but in each case, I do not have the space here to substantiate it.

Table 1 Summary of geophysical limits, main risks potentially transferred, and the respective roles in climate policy of mitigation, adaptation, NETs and SRM

Climate intervention	Practical and geophysical constraints	Main risks potentially transferred to vulnerable and poor people, future people, and non-human nature	Role in climate policy
Emissions reductions (Mitigation)	Legacy emissions; carbon lock-in in current infrastructure; most-difficult-to-abate emissions	Negative impacts on Indigenous peoples and on non-human nature of some strategies*; impeding poverty alleviation and development*; residual social and environmental impacts of technological options	Central pillar – main efforts should be concentrated here and efforts must be rapidly accelerated to realise ambitious emissions reductions
Adaptation	Limit to how much climate change we can adapt to; costs escalate with higher warming	Cultural losses; maladaptation	Essential to alleviate impacts of global warming we are already committed to – should be kept as limited as possible to reduce risks and cultural losses
Negative emissions technologies (NETs)	Sustainability constraints of BECCS; limited potential to extract CO_2 per DACCS facility; challenges at storage side	Burden of large-scale deployment postponed to future; infeasibility of upscaling	Necessary to tackle the most-difficult-to-abate and legacy emissions – should be reserved for these emissions only
Solar radiation management (SRM)	Robust, long-term governance required; exacerbated negative impacts of large-scale deployment	Direct negative impacts of SRM; indirect impacts resulting from CO_2 accumulation; burden of tackling CO_2 accumulation postponed	Fallback option – should be avoided or, if unavoidable, be kept as limited as possible

* These risks are not inherent to mitigation; as I have argued in Sect. 4, they can be avoided by selecting mitigation strategies without such risks

erode our commitment to ambitious emissions reductions. The defeatist view that takes the failure of mitigation as a given results in a self-fulfilling prophecy because it will increase mitigation deterrence and therefore also the extent to which we will have to rely on adaptation, NETs and SRM. Especially illuminating is that the moral hazard can be traced back to the liberal-capitalist worldview. Ambitious decarbonisation conflicts with this dominant social paradigm: it unsettles materialistic freedoms, the imperative of economic growth, consumerist lifestyles and the vested interests in a fossil-fuel based economy. In contrast, the supplementary climate interventions leave the liberal-capitalist worldview largely unchallenged. Of significant moral import, though, is that perpetuating the liberal-capitalist worldview through reliance on the supplementary interventions rather than ambitious decarbonisation will result in a significant transfer of risks. Affluent and polluting people of the present would in this way protect their profligate lifestyles and vested interests in the fossil-fuel based economy at the expense of imposing severe risks of grave losses on poor, vulnerable and future people, as well as non-human nature.

In the title of his chapter to *The Oxford Handbook of Environmental Ethics*, Shue, 2017a, 2017b, p. 465) calls mitigation the 'first imperative of environmental ethics.' I believe in fact that we should go a step further and *double down* on urgent

and ambitious emissions reductions. Even with excluding those options and strategies that are not desirable due to the potential transfer of risks they may cause, there is still a huge untapped potential to reduce emissions. Adaptation, NETs and/or SRM may be necessary – to some extent or as a fallback – alongside mitigation to ultimately tackle climate change, we can still prevent a large proportion of climate change by *doubling down* on urgent and ambitious emissions reductions.

Acknowledgements This paper was inspired by discussions with my students on the module "Climate and Environmental Ethics" (2023-24). I am grateful to them for putting me on the path towards further analysis of this topic.

Author Contributions The full paper was written by Wouter Peeters.

Funding The author declares that no funds, grants, or other support were received during the preparation of this manuscript.

Data Availability Not applicable.

Declarations

Competing Interests The author declare no competing interests.

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