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Assessing climate policies: Catastrophe avoidance and the right to sustainable development

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Abstract

With the significant disconnect between the collective aim of limiting warming to well below 2°C and the current means proposed to achieve such an aim, the goal of this paper is to offer a moral assessment of prominent alternatives to current international climate policy. To do so, we'll outline five different policy routes that could potentially bring the means and goal in line. Those five policy routes are: (1) exceed 2°C; (2) limit warming to less than 2°C by economic de-growth; (3) limit warming to less than 2°C by traditional mitigation only; (4) limit warming to less than 2°C by traditional mitigation and widespread deployment of Negative Emissions Technologies (NETs); and (5) limit warming to less than 2°C by traditional mitigation, NETs, and Solar Radiation Management as a fallback. In assessing these five policy routes, we rely primarily upon two moral considerations: the avoidance of catastrophic climate change and the right to sustainable development. We'll conclude that we should continue to aim at the two-degree target, and that to get there we should use aggressive mitigation, pursue the deployment of NETs, and continue to research SRM.

Keywords

climate change, degrowth, mitigation, negative emissions, geoengineering, sustainable development

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Introduction

In 2015, the global community reaffirmed its commitment to combat climate change. As stated in the Paris Agreement, the aim is to limit the 'increase in the global average temperature to well below 2°C' and to pursue efforts to 'limit the temperature increase to 1.5°C above pre-industrial levels' (United Nations, 2015). To be sure, it is not as if there are no risks associated with temperature increases of well below 2°C. Some recent research supports the claim that certain risks, in particular risks of extreme daily temperatures and extreme daily precipitation, increase considerably when the mean temperature increases from 1.5°C to 2°C (Kharin et al., 2018). Still, the 'well below' 2°C target is the agreed-upon aim. Unfortunately, the means to achieve such an aim are far from clear. What *is* clear is that the means outlined in the Paris Agreement are currently insufficient to limit warming to well below 2°C.

The overall reduction pledged in Paris comprises an aggregation of individual contributions from 197 different parties representing nearly the entire global population. Each party submitted their 'Nationally Determined Contribution' (NDC), outlining the efforts they would contribute toward reaching the collective goal of limiting warming to well below 2°C. Recently a great many countries have been updating their pledges and importantly making net zero pledges. According to one credible analysis of these recent pledges, if they were met, the temperature would stabilize at between 1.7 and 2.7°C (Climate Action Tracker, 2021). There is room then for considerable concern that current policies are ambitious enough to limit warming to 2°C. Obviously then success in limiting warming to no more than 1.5°C is even less likely.

With the uncertainty between the collective aim of limiting warming to well below 2°C and the current means proposed to achieve such an aim, the goal of this paper is to offer a moral assessment of several available alternatives to current international climate policy. To do so, we'll outline five different policy routes that could potentially bring the means and goal more tightly in line. We have chosen these five because our survey of policy discussions suggests that they each command some allegiance in political circles. We certainly do not suppose that these are exhaustive of all policy responses. Still, each of the five is worthy of consideration.

The five policy routes we survey are: (1) exceed 2°C; (2) limit warming to less than 2°C by economic degrowth; (3) limit warming to less than 2°C by traditional mitigation only; (4) limit warming to less than 2°C by traditional mitigation and widespread deployment of Negative Emissions Technologies (NETs); and (5) limit warming to less than 2°C by traditional mitigation, NETs, and Solar Radiation Management as a fallback.

Ideally one would offer an assessment of *all* the available alternatives in the name of comprehensiveness. For example, there may be combinations of some of the above proposals that will come to seem particularly promising. Or perhaps it would be ideal to offer necessary and sufficient conditions that an ideal climate policy would fulfill. This is not the methodology we employ here. Rather, we offer a comparative assessment of only the five alternatives that we judge to have fairly significant support in policy debates. One thing is perfectly clear: there are trade-offs to be made with respect to each policy route; there is no risk-free approach.

In the following section we'll introduce two moral considerations we think ought to be used when assessing these five policy routes. In section 3, which makes up the bulk of the paper, we'll employ these considerations when making our moral assessment. We'll conclude that we should continue to aim at the two-degree target, and that we should use aggressive mitigation, pursue the deployment of NETs, and continue to research SRM to get there.

Moral considerations for climate policy

The IPCC rightly states that 'many areas of climate policy-making involve value judgments and ethical considerations' (2014b). When it comes to evaluating climate policies from an ethical perspective, we outline two considerations that ought to be taken into account. The first consideration is that any climate policy should seek to avoid catastrophic climate consequences. The second consideration requires that our global climate policy respect the right to sustainable development. These two considerations are both highly plausible morally and familiar to the United Nations Framework Convention on Climate Change (UNFCCC,).[1]

Catastrophic climate consequences

An arguably more demanding objective to 'prevent dangerous anthropogenic interference with the climate system' is stated in Article 2 of the 1992 UNFCCC. We assume that catastrophic change counts as dangerous change, although the class of dangerous changes is plausibly larger than only catastrophic change (Moellendorf, 2014). In any case, the moral importance of avoiding catastrophic climate consequences cannot be reasonably denied. Indeed, if there is reasonable criticism of the principle, it is that it is too weak. That may well be since intergenerational justice might require considerably more than only the avoidance of catastrophe. There is controversy, however, about what exactly intergenerational justice requires. Catastrophe avoidance recommends itself both because it is implied by the UNFCCC objective and because there can be no reasonable denial of the principle.

A reasonable moral principle expressed in the UNFCCC has important practical force. Two points stand out here. First, the fact that a party has ratified the treaty entails a promissory obligation to respect its norms. Thus, for parties to the UNFCCC, norms within the Convention have moral force (Moellendorf, 2014, 2011). It would be unreasonable, of course, to maintain that promissory obligations are absolute. There may be lesser-evil justifications for failing to honor promises under some conditions. But promises are widely understood to entail *pro tanto* obligations to honor them. Second, because climate change negotiations are beset with collective action problems, maintaining commitments made within a treaty context is especially important for fostering and maintaining the relationships of trust between parties acting in concert to solve the problem of climate change.

It is difficult to give a precise definition of a catastrophic climate consequence. That difficulty notwithstanding, when we refer 'catastrophic' consequences we generally mean massively costly outcomes that exceed human adaptive capacity. These could result from an increase in the frequency and intensity of extreme weather events or the surpassing of certain tipping points in the Earth's systems. A paradigm example the latter would be the near-complete loss of the Greenland ice sheet. A near-complete loss of the Greenland ice sheet would carry with it global mean sea level rise of roughly 7 m (IPCC, 2014a). A global mean sea level rise of 7 m would be catastrophic in that it would inundate many large coastal cities – for example, Osaka (Japan), Alexandria (Egypt), New York City (USA), Rio de Janeiro (Brazil), Shanghai (China), and Dhaka (Bangladesh), to name a few. Such inundation would surely outstrip our adaptive capacity in many regions and cause massive displacement of tens of millions of people. While there is currently insufficient understanding to know what specific increase in average global surface temperature would cause the Greenland ice sheet to collapse, scientists estimate that it is above 1°C and below 4°C (IPCC, 2013). With our current emissions trajectory pushing us toward 2.7°C of warming, we are currently pursuing a climate policy that, with some likelihood, will engender catastrophic climate consequences.

The complete or near-complete loss of the Greenland ice sheet is a paradigm example of a catastrophic climate consequence. But there certainly other climatic consequences that would count as catastrophic as well. Significant species loss, famines, prolonged droughts, heat waves, and intense storms could all count as catastrophic climate consequences.

The right to sustainable development

A second moral consideration relevant to climate policy is the right to promote sustainable development. The right to promote sustainable development has been enshrined in international climate policy for decades. Article 3 Section 4 of the UNFCCC states that 'responses to climate change should be coordinated with social and economic development in an integrated manner with a view to avoiding adverse impacts on the latter, taking into full account the legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty' (United Nations, 1992). Twenty-five years later with the Paris Agreement, the parties reaffirmed that the global response to climate change must respect and promote the right to sustainable development (United Nations, 2015).

The right to promote sustainable development makes it clear that global climate policy cannot justifiably ask developing countries to forgo their ambitions in poverty eradication. The right then should be understood as a liberty for states to pursue poverty-eradicating human development plans. But the qualifier 'sustainable' in the right to sustainable development implies that development ambitions must be constrained so as not to undermine the just entitlements of future generations (Moellendorf, 2011). The best way to understand the sustainable qualifier in the climate context is with respect to cumulative global emissions. Because increases in average surface temperature (and to a lesser extent, corresponding climate perturbations) are roughly linearly related to total global emissions, 'The right to sustainable development is the right to develop in the context of a sustainable *global* energy policy' (Moellendorf, 2011).

To provide a concrete example, the right to promote sustainable development would rule out a global climate policy that required the Central African Republic, Niger, or

Chad – the three countries with among the lowest HDI rankings – to stall or even significantly curtail their development ambitions. Countries like the Central African Republic, Niger, and Chad have a right to pursue poverty-eradicating development. That will require significant protection, either by means of mitigation or adaptation to climate change. But it also requires massive energy consumption and economic growth. Acquiring such energy at low costs is a legitimate interest of least developed and developing states. While a climate policy that thwarted the development ambitions in these countries would be the paradigmatic transgression of the right to sustainable development, there are, of course, other climate policies that would also transgress the right.

Other moral considerations

The two considerations that we rely on here are not the only possible considerations relevant to a moral assessment of climate policies. But we see them as among the most relevant, both because they are reasonable and because they have the virtue of being well-established UNFCCC norms (Moellendorf, 2016). As we mentioned above, a more demanding intergenerational principle could be employed. Or one could argue in favor of a strong redistributive principle that would address not only climate change but also other global inequities that are often cited as unjust. While we are sympathetic to such concerns, we shy away from leaning on more demanding moral considerations for three reasons. First, as stated earlier, the fact that parties have already agreed to both avoid catastrophe and respect the right to promote sustainable development creates promissory obligations to do so. Second, more demanding redistributive or intergenerational principles of climate change are controversial. Given the narrow window we have to act on climate change, we have good reason to rely upon less controversial principles that are still consistent with the demands of morality and justice. Finally, substantial insight can be had by the considerations we employ here. We doubt that other moral principles would decide trade-offs much differently than catastrophe avoidance and the right to sustainable development.[2]

In the following section we'll assess the prospects of the five policy routes mentioned in the introduction. Each of these policy proposals has its defenders in the literature. But no one to date has offered a comparative assessment of these alternatives based upon the two moral considerations just outlined, which is exactly what we do in the following section. We'll first present a descriptive explanation of the policy route, and then use the aforementioned considerations to offer a moral assessment.

A moral assessment of the available alternatives

Exceed 2°C

Perhaps the first reaction one might have to the insufficiency of mitigation efforts to achieve the internationally agreed upon goal is that we should simply choose a more easily attainable goal for climate policy. In other words, perhaps we should exceed the 2°C limit. After all, 2°C of warming above pre-industrial averages is not a magic number. Indeed, the temperature target's relationship to emissions, which can be directly controlled, is indirect and uncertain.[3] Moreover, there are climate risks associated with warming of less than 2°C, and there will be climate risks associated with warming greater than 2°C. Why stick to such an arbitrary target like 2°C?

The thought of exceeding the two-degree target is not popular politically, but it has some prominent proponents. Ted Nordhaus recently penned a piece titled 'The Two-Degree Delusion' (Nordhaus, 2018). Nordhaus claims that the goal of limiting warming to 2°C is not only naïve in the sense of being practically unachievable, but also detrimental in the sense that it leads to the exclusion of potentially beneficial transitional energy sources like natural gas – energy sources that are cleaner than traditional fossil fuels, but still too 'dirty' to carry us to the two-degree goal (2018). Given both the claimed unachievability and the purported negative consequences of myopically focusing on the ambitious two-degree goal, Nordhaus concludes: 'Sustaining the fiction that the two-degree target remains viable risks leaving the world ill prepared to mitigate or manage the consequences' of a world warmed beyond 2°C. The upshot of Nordhaus' argument is we ought to revise our two-degree goal upwards.

There are two compelling reasons to believe that revising the two-degree target upwards would be a grievous mistake. One is the thought that revising the target upwards is likely to transgress the right to promote sustainable development, the other concerns the risk of setting in motion climate perturbations that would be catastrophic.

Climate change mitigation and adaptation policy have an important relationship to one another. Although it is a gross simplification to do so, one can think of this relationship as two different policy approaches to containing the costs of climate change. If one were aiming to prevent loss and damage above some threshold, the less one mitigated the more one would have to adapt. Hence, reducing mitigation costs involves transferring costs to adaptation. The suggestion by Nordhaus could be understood then as kind of accounting transfer from mitigation to adaptation, assuming that he is not advocating allowing a greater package of damages to come to pass.

The accounting transfer is, however, unlikely to be morally neutral. Although robust mitigation must be initiated in the next few years in order to limit warming significantly, investment in adaptation can be delayed. This is because the full warming associated with any concentration of greenhouse gases is not likely to occur until much later in the century. The intergenerational transfer of costs may not seem worrisome since it would likely be progressive on average. In 50 or more years the global economy is projected to be much larger and people will be on average correspondingly much richer. But any such consolation is lost when one adopts a finer grained analysis. Mitigation is necessarily a global project, requiring international cooperation to be effective, and therefore needing some sort of international cost-sharing scheme. Protecting against the effects of climate change by means of adaptation, in contrast, involves local measures, and the costs – though they shouldn't be – can be left to individual states. In other words, although successful mitigation requires cost-sharing, adaptation does not. And since it does not, cooperation is even harder to foster. For example, the global community has pledged to provide the Green Climate Fund with 100 billion USD *annually* to fund adaptation projects. Since its conception in 2010, a mere 10.2 billion USD has been pledged to date, leaving many of the most vulnerable states with large poor populations especially vulnerable to climate change (Green Climate Fund, 2018).

To illustrate the point that foregoing mitigation to pursue adaptation risks a regressive cost assignment, consider the Ganges Brahmaputra Delta in Bangladesh and West Bengal, India where, according the World Bank, more than 30 million people live below the poverty line and are increasingly vulnerable to climate change, ocean inundation in particular (Sieghart, 2015). Transferring a measure of the costs from mitigation to adaptation could be devastating to place like the Delta. Pursuing such a policy threatens the right of sustainable development unless significant redistribution measures are implemented – something that the history of the Green Climate Fund shows to be unlikely.

The second reason not to revise the temperature target upwards is the risk of unleashing catastrophic consequences. Climate change risks increasing the incidence of drought and crop failures, particularly in warm regions of the world (IPCC, 2015). It also risks undermining food security (IPCC, 2015). These concerns become even graver in the context of a growing global population. The more warming allowed by policy, the more droughts are risked and the more crop production is risked. In an interconnected world, diminished crop production raises global food prices, affecting most severely food-*importing* countries. The effects of a drought in Russia or the United States can be hunger or political instability in the Middle East, North Africa, or Sub-Saharan Africa. Each of these regions relies heavily on food imports for a large fraction of the calories people consume (National Academies, 2013). Due to global food supply chains, it is not hard to envisage how a mega-drought in one part of the world could create mass hunger in some entirely different region of the world. The higher warming is allowed to go, the greater the likelihood of abrupt changes, such as methane release from arctic stores, or irreversible events, such as ice sheet collapse. Events in these two categories would, of course, also be catastrophic.

In sum, exceeding the 2°C warming goal is objectionable in light of both of the moral considerations we highlighted. Exceeding 2°C would require underdeveloped countries to invest soon in expensive adaptation programs, for which they have little capital, or to leave their citizens to experience very significant loss and damages. This would violate the right to promote sustainable development. Additionally, the failure to limit warming also risks putting people later in the century in a position of suffering catastrophic consequences.

There is nothing special about 2°C in particular. It would be a mistake to claim that dangerous climate change begins at 2.1°C. Identifying dangerous climate change involves moral judgment, and necessarily involves considering alternatives (Moellendorf, 2014). But the science is clear that the risks of climate change outstripping adaptive capacity increase as warming increases. Even increasing warming from 1.5 to 2°C carries significant risk of extreme weather events (IPCC, 2018; Kharin et al., 2018). This is where the proposal to 2°C faces a dilemma. If the proposal calls to revise the target only slightly upwards – say, to 2.1 or 2.2°C – then it is unlikely to lead to the inclusion of alternative energies like natural gas that are 'too dirty' to be compatible with the 2°C goal. But if the proposal is to revise the target upwards significantly – say, to 2.5 or 3°C – then it would run too high a risk of engendering catastrophic climate change and violating the right to sustainable development. Hence, there are compelling reasons not to revise the warming limit upwards

Limit warming to less than 2°C by economic degrowth

Of the policy proposals that accept the 2°C limit, the proposal that suggests we mitigate emissions by limiting economic growth – or engaging in degrowth – is perhaps the most radical. In broad strokes, the proposal is intuitive enough. There is clearly a strong connection between economic activity and greenhouse gas emissions: more economic activity, more greenhouse gas emissions (United Nations Development Program, 2015). The simple thought is that if we want to limit the latter, we can do so by decreasing the former.

The proposal of limiting economic growth, like that of exceeding the 2°C limit, is anything but popular politically speaking. Kevin Anderson and Alice Bows-Larkin, however, defend it. Anderson and Bows-Larkin argue that in order for us to have a reasonable chance of keeping warming below 2°C, 'the wealthier (Annex 1) nations need, temporarily, to adopt a degrowth strategy' (Anderson and Bows, 2011).

Anderson and Bows-Larkin think that the degrowth conclusion follows from a number of reasonable assumptions. For instance, if we accept the 2°C limit (specifically, a 50% chance of keeping warming below 2°C), in conjunction with the equity-oriented commitment to letting Non-Annex I countries continue to develop (specifically, letting their emissions increase until 2025 and then subsequently decreasing at 7% per year), then Annex I countries will have to reduce their emissions by 8–10% per year immediately (a rate that, they claim, *requires* degrowth). This leads them to conclude that, if we want to hit 2°C, then economic growth must be exchanged '...at least temporarily for a period of planned austerity within Annex 1 nations' (Anderson and Bows, 2011).[4]

Our main concern is that given present global economic integration – which we assume cannot be changed within the time frame in which a response to climate change must be developed – any such austerity is highly unlikely to be compatible with the right to promote sustainable development. Anderson and Bows-Larkin seem to think that 'planned austerity' can be limited to Annex 1 countries. But there are compelling reasons to think this is unlikely as things now stand. The world conducted an unintentional experiment with degrowth during the Great Recession of 2009. Global CO_2 emissions fell by about 1 percent that year (World Bank, 2018). As a result of the Great Recession, world economic growth fell from a rate of 3.9 percent in 2007 to 3.0 percent in 2008 all the way down to −2.2 percent in 2009 (World Bank, 2010). The recession was not contained to the developed world. Emerging and developing countries saw growth rates fall from 8.3 percent in 2007 to 8.1 percent in 2008 and down to 1.2 percent in 2009 (World Bank, 2010). The World Bank estimates that for every percentage point in growth lost, 20 million people are trapped in poverty (United Nations, 2009). In our financially interconnected world, crisis transition mechanisms serve to pass recessions in the developed world to poor countries through reduced investment by corporations, reduced remittances by individuals, and decreased demand for basic commodities from poor countries (Moellendorf, 2020). Absent a major overhaul of the global economy this will not change. Is such an overhaul possible? In principle yes, but we doubt such an overhaul is possible within the urgent time frame available for responding to climate change.

The degrowth position is morally untenable in light of the effects of austerity on global poverty. The position would almost certainly violate the right to promote sustainable development. To make matters worse, austerity would likely result in very little gain for the mitigation effort. Recall that in the biggest recession in recent history emissions only fell by 1 percent. Robert Pollin argues that in order to reduce emissions by 10 percent, the global economy would have to contract by 10 percent (Pollin, 2015). Suppose the economies in the emerging and developing world contracted by the same percentage, as in the last recession. According to World Bank estimates regarding reduction in growth, the 10-percentage point decline in emissions achieved in that manner would come at the price of trapping 200 million people in poverty. We see no plausible moral defense of pursuing a policy that would have such an effect.

Limit warming to less than 2°C by traditional mitigation only

Obviously, emissions reductions will be central to any sensible climate policy. But the criticisms of the degrowth approach suggest that the aim of limiting warming to below 2°C should be pursued by means *consistent* with maintaining economic growth, especially so as to allow poverty eradication through sustainable development.

The most conventional proposal for meeting the two-degree target – and the one actually embedded in the Paris Agreement framework – is the idea of ratcheting up traditional mitigation efforts. Traditional mitigation efforts do not require degrowth. Rather, they assume economic growth and higher demands for energy, and assume that we will be able to supply those greater demands with alternative forms of energy production.

The alternative forms of energy production the traditional mitigation proponents have in mind vary. For instance, Robert Pollin advocates a mitigation-only strategy that, in addition to energy efficiency improvements, relies upon solar, wind, geothermal, bio-, and hydro-energy. Noticeably absent from this list is nuclear power. Solar, wind, geothermal, bio-, and hydro-energy currently make up less than 1% of global energy supply (Pollin, 2015: 45). Currently, the world devotes roughly 0.4–0.6% of global GDP toward investments in renewable energy (Pollin, 2015: 8). But Pollin argues that with additional annual investments of merely 0.75% of global GDP – coupled with investments of 0.75% of global GDP going to improvements in energy efficiency – the suite of renewable energy sources he outlines could satisfy one third of global energy demand by 2035 (Pollin, 2015: 8). The goal that Pollin has in mind is global GHG emissions 40% lower than 2010 levels by 2035 and 80% lower by 2050 (a goal consistent with the IPCC's RCP's that stand a good chance of limiting warming to 2°C).

Clearly, devoting 1.5% of global GDP to investments in energy efficiency and renewables won't happen overnight.[5] This is why the language of 'ratcheting up' efforts is so important. The thought is to have mitigation efforts incrementally increased over time. This is much more realistic than an immediate and drastic reallocation of capital. But, as should be clear, the less aggressive the increase in investments now, the more aggressive the increase in investments will have to be in the near future.

Anthropogenic warming is a function of greenhouse gases in the atmosphere that derive from human activity. The concentrations of these gases are functions of previous stocks and cumulative emissions. One apparently serious problem with limiting warming to less than 2°C by means emissions-reductions-only is that the present concentration is already higher than the level that the IPCC judges as likely necessary in order to limit warming that much. The IPCC holds that, 'Mitigation scenarios in which it is *likely* that the temperature change caused by anthropogenic GHG emissions can be kept to less than 2°C relative to pre-industrial levels are characterized by atmospheric concentrations in 2100 of about 450 ppm CO_2eq' (IPCC, 2014b). But according to the US National Oceanic and Atmospheric Administration (NOAA), atmospheric greenhouse gas concentrations had already reached 500 ppm CO_2 eq in 2019 (NOAA, 2020). To be sure, some of the greenhouse gases are cycled through the atmosphere faster than CO_2. And there may be disagreements about measurements or about the conversion of other greenhouse gases into CO_2 equivalents. But the NOAA data is sobering.

The existing concentration of greenhouse gases in the atmosphere raises serious doubts about whether merely ratcheting up mitigation can limit warming to below 2°C. And as we have argued, allowing the temperature to increase beyond 2°C threatens both the right to sustainable development and seems to risk catastrophe. Even at the time of the publication of the AR5, the prospects of an emissions-reductions-only policy looked poor. Eighty-seven percent of the projections surveyed in the IPCC's AR5 that hold concentrations to between 430 and 480 ppm CO_2 eq rely on some form of negative emissions in addition to traditional emissions reductions (Smith et al., 2016). At that point projections referred to a base year of 2011 when the atmospheric concentration of greenhouse gases was significantly lower (430 ppm CO_2 eq) (IPCC, 2014b). Seven years later, with global emissions still on the rise, the prospects for an emissions-reductions-only policy are much worse.

Let's assume a more optimistic geo-physical picture. Perhaps as emissions decline, the overall volume will fall sufficiently below that natural rate at which CO_2 and other greenhouse gases are recycled out of the atmosphere so that concentrations will in time fall to 450 ppm CO_2 eq. Carbon Brief has presented a model indicating the geo-physical possibility (Carbon Brief, 2017). The Carbon Brief scenario requires immediate global reductions, falling steadily to around 22 percent of 2015 levels in 2040, and then more slowly toward zero by around 2065. A 78 percent drop in 23 years is steep. The annual rate of decline quickly reaches 5 percent by 2023 and 9 percent by 2034. By comparison this a much steeper rate of decline than Pollin foresees, assuming the mitigation effort started in 2012. According to his plan, every country is to contribute a maximum of 2 percent of GDP per year (Carbon Brief, 2017). The more ambitious Carbon Brief scenario would require a larger annual investment.

Even optimistically assuming that it is geo-physically possible to limit warming to below 2°C through emissions reductions only, there are still several compelling reasons to doubt that the emissions-reductions-only strategy could be effective in achieving the aim. The hurdles to effecting such a policy are tall, even when assuming basic good will among international negotiators. We briefly sketch five hurdles.

First, the overall character of international negotiations is marked by serious collective action problems. Even though climate change mitigation is in the interest of every state negotiating, for most if not all parties, it also in their interest not to assume the full costs of an energy transition (no matter what other parties do). The analysis does not have to assume corrupt moral intent. Leaders may have the interests of their citizens in mind, and these interests may include such important aims as poverty eradication. Climate change mitigation can retard that process. A central authority could ensure compliance, but that simply pushes back the problem to the creation of the authority. Humans have discovered ingenious ways to solve these problems (Ostrom, 2015). But whether it can be done in sufficient time in the present case is an open question.

Robert O. Keohane and David Victor argue that there are several exacerbating features of the present case. These include a wide variety of interests among states, uncertainty about the risks of climate change and the benefits of cooperation, insufficient linkages between states for establishing incentives to cooperate, a multiplicity of problems requiring cooperation, and a lack of political capacity in some states to regulate appropriately (Keohane and Victor, 2011). In a separate work Victor has pointed to additional hurdles, including the size of the negotiations and the unanimity norm for decisions, the distinction between government representatives who make agreements and the private actors they must regulate, and the lack of full control over achieving the aim (Victor, 2011). These factors conspire to produce relatively unambitious aims.

Second, even if an ambitious proposal were agreed upon and an enforcement agency were created, we are still learning which policy instruments work best. According to a World Bank report, half the world economy and a quarter of all greenhouse gas emissions are currently governed by carbon pricing schemes, including emissions trading schemes and carbon taxes (Muûls et al., 2016; World Bank, 2017). Setting the quantity of entitlements under the former and the rate for the latter requires considerable trial error. Learning by doing will necessarily be a feature of these sorts of regulatory efforts. According to the report, ‘About three quarters of emissions covered by carbon pricing are priced at less than US\$10/t CO_2 eq. This is substantially lower than the price levels that are consistent with achieving the temperature goals outlined in the Paris Agreement, which are in the range of US\$40–80/t CO_2eq in 2020’ (World Bank, 2017). The problems with these schemes are not merely due to the fact that we need to learn more, however. They also derive from the nature of collective action problems. Domestic jurisdictions are concerned about international competitiveness, long-term international commitment, and inadequate international trust (World Bank, 2017).

Third, even if we knew exactly how to regulate emissions effectively and efficiently, vertically coordinating the actions of multiple agents responsible for such regulation would still present a problem. As the World Bank report noted, state and subnational units have sometimes been reticent to adopt robust mitigation aims in the absence of clear international commitments. And Victor notes the problem that international negotiators are also concerned not to make commitments that cannot be realized due to lack of capacity to compel the outcome domestically (Victor, 2011).

Fourth, capriciousness of democratic politics and legislative reversals have posed serious problems for international cooperation to bring about substantial climate change mitigation. After a new election in 2014, Australia repealed its carbon tax. And US President Donald Trump announced in 2017 that the USA intended to withdraw from the Paris Agreement, which had been negotiated in part by President Barack Obama.

Finally, because the energy transition within states will not lead to a Pareto Superior outcome, parties that stand to lose can be expected to offer resistance. The fossil fuel industry has significant interests in the status quo policy regime. According to the International Energy Agency, no more than a third of coal reserves can be burned without using some form carbon dioxide removal if the 2°C goal is to be achieved (IEA, 2012). Presumably, the industry will resist legislative attempts to block access. Additionally, that industry can be expected to fight hard to maintain the declining subsidies that it receives (IEA, 2020).

These hurdles suggest that making a rapid transition to a zero-carbon global economy will be exceedingly difficult. But one might wonder whether there is genuine difficulty in traversing these hurdles, or whether we just aren't putting enough effort into jumping. Henry Shue criticizes the moral character of the policy-makers who, according to him, insufficiently pursue mitigation. He asserts that it 'may be an especially clear example of what Stephen M. Gardiner calls "moral corruption." Moral corruption is actually corrupt moral reasoning, but the reasoning is corrupted by a moral failing constituted by assigning inordinate weight to one's own well-being at the price of the well-being of others that justice would require one to respect' (Shue, 2017).

Our argument does not engage in any such objectionable weighing of interests. We readily recognize the importance of considering the interests of future generations. But at least the first three of the difficulties we cite above suggest that, assuming it is geo-physically possible, even if there were good will, it would still be unlikely that we could make a rapid and accelerated change in the direction of ramping up mitigation so as to limit warming to below 2°C.

On our view, there are grave doubts about the likelihood of success for any policy effort that aims to limit warming to below 2°C through emissions reductions only, and these derive from both geo-physical constraints and the enormity of the social and political transition involved. To pursue the aim of limiting warming to below 2°C by means of an emissions-reductions-only policy would be to assume a high risk of failure. It is far from clear anymore that such means are geo-physically possible. But even if they are, transforming the basis of the global economy at the rate that would be required by an emissions-reductions-only scenario is very unlikely in light of the hurdles just surveyed. Both the physics and the political economy raise the concern of risking catastrophic climate change. The emissions-reduction-only approach creates a substantial risk of winding up unintentionally where the revising the target upward strategy intends to go. And it thus suffers from the same moral objections as that policy.

Limit warming to less than 2°C by traditional mitigation and widespread deployment of negative emissions technologies (NETs)

The overwhelming majority of the scenarios that the IPCC considers consistent with RCP 2.6 rely on removing carbon from the atmosphere.[6] In order to bridge the gap between what can be done with traditional mitigation and what is needed in order to limit warming to less than 2°C, a category of technologies known as Carbon Dioxide Removal (CDR) or Negative Emission Technologies (NETs) are increasingly thought to be necessary (Energy Transitions Commission, 2020). NETs comprise a cluster of proposals that would remove greenhouse gases (mainly, CO_2) from the atmosphere. Importantly, no one is advocating the use of NETs in isolation. For those who think NETs will have a role to play in future climate policy, it is universally recognized that they must be accompanied by increased mitigation efforts.

Two of the most commonly discussed approaches to negative emissions are Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Capture with Storage (DACS). BECCS involves a four-step process. First, particular crops of biomass are cultivated. Second, these crops are burned to produce energy. Third, the emissions from this combustion are captured before they dissipate into the atmosphere and, finally, the carbon emissions are securely stored so that they do not contribute to climate change. DACS would use technologies that are able to sequester CO_2 directly out of the ambient air through the use of chemicals that bind to the carbon dioxide molecules. Once the CO_2 has been sequestered, it can then be stored so that, as with BECCS, the gas doesn't contribute to temperature increases.

Combining NETs with traditional mitigation approaches could help us reach the two-degree goal. Most climate models require global GHG emissions to be negative at some point in the second half of the 21st century. Of course, these negative emissions might be achieved through means other than BECCS and DACS – such as mass afforestation, enhanced weathering, or ocean fertilization – but BECCS and DACS are commonly discussed as more realistic policy options. Although the potential of NETs to contribute to limiting warming might be considerable, the technology to employ them at the scale required in the climate models does not yet exist. If there is to be an alternative to a likely overshoot of 2°C resulting from insufficient emissions reductions, policy makers should encourage and incentivize considerable research and development into NETs.

There will be limits to the use of NETs due to the land, water, and energy required to deploy them. The limits seem to vary by the kind of technology employed. For example, BECCS is land- and water-intensive, but generates energy. DACS requires energy consumption, but is much less land- and water-intensive (Smith et al., 2016). There is controversy about the extent to which the employment of BECCS will affect sustainable development due to its land and water use. Shue asserts that the land and water removed from farm use 'seem almost certain to drive up [crop] prices' (Shue, 2017). But Shue's is an a priori claim, and he seems to consider only one factor in the price of crops: namely, the availability of land. In fact, the price of crops also depends crucially on the carbon price. Introducing a carbon price, as required by mitigation, will in any case increase crop prices, but mitigation with NETs is likely to have a *lower* carbon price than mitigation without since the phase out of fossil fuels can happen somewhat more slowly. The net effect on food crop prices, according to at least one economic model, is that although any significant mitigation will raise crop prices, the price increase will be *lower* with NETs than without it, even for BECCS (although less so) (Muratori et al., 2016). The modeling suggests that a policy of emissions-reductions-only could be more detrimental to sustainable development aims than one that employed NETs. Hence, Shue's conclusion that BECCS technology 'has completely unacceptable moral costs' is doubtful in light of existing economic evidence (Shue, 2017: 206).

Although not critical of research into NETs altogether, Kevin Anderson and Glen Peters refer to them as 'a moral hazard par excellence' (Anderson and Peters, 2016). But a worry that NETs might establish a moral hazard seems to suggest that the task of limiting warming to below 2°C is readily achievable if only the will were there. We argued in the previous section that – in light of geo-physical limits and the complexity of the social and political transition – that seems highly doubtful. Because we are skeptical that simply ratchetting up mitigation can work, we do not find concerns about creating a moral hazard decisive.

Especially after the publication of the IPCC's Special Report on 1.5°C, it seems as though NETs will have to play at least some role in our future climate policy portfolio. But there are at least two main worries about relying too heavily upon NETs. The first is the worry of risk transfer; the second is that of overshoot.

Shue as well as Anderson and Peters are concerned about transferring risk of failure to future generations. The basic concern goes like this. If NET research fails to provide a scalable technology, then relying on it will place people in the future in terrible circumstances. To be sure, the concern about scaling the technology up to the point where it is making a significant impact on atmospheric GHG concentrations is warranted (Honegger and Reiner, 2018). According to a recent article by Dominic Lenzi et al., there are currently 3 biomass power plants with carbon capture and storage being used (Lenzi et al., 2018). In order to sequester the amount of CO_2 required by some of the IPCC scenarios that rely upon NETs, those three BECCS plants would have to become 16,000 BECCS plants by 2050 (Lenzi et al., 2018). The employment of such technology would allow for net zero emissions, when the gross is not yet zero. The recent wave of countries pledging net zero emissions rely on the development of such technology. Of course, if the policy is to develop the technology and to build some 16,000 plants, but it turns out that delivering on such a plan is infeasible, it is future generations who will bear the brunt of the catastrophic warming.

We certainly cannot count on NETs delivering everything they promise given our current knowledge.[7] And we agree that transferring risks to future generations is something we should guard against. But in the present case, given the weak prospects of mitigation only, *not* pursuing research and development of NETs seems riskier for future generations. We should be warry about relying upon negative emissions technology to the detriment of mitigation, but it seems nearly certain that it will have to play a role in the policy response. But even if we assume both that the technology can be scaled up at the required rate and that the ambition to fund such an effort will materialize, we have another reason to worry about a reliance on NETs – namely, concentration overshoot. The concentration overshoot worry can be succinctly summarized with a quotation from Henry Shue: 'temporary changes can produce permanent effects' (Shue, 2018).

To restate the facts, in order to be likely to limit warming to below 2°C by 2100 we need to stabilize atmospheric GHG concentrations at 450 CO_2 eq ppm (IPCC, 2014b). The overwhelming majority of models that sufficiently limit atmospheric concentrations by 2100 actually involve a temporary overshoot of 450 CO_2 eq ppm. Recall that we were already at 500 ppm CO_2 eq in 2019. Accompanying this temporary concentration overshoot could be a temporary overshoot in the target of 2°C. And this temporary temperature overshoot could produce permanent changes. Consider the following hypothetical scenario from Shue.

New research within glaciology suggests that the Thwaites and Haynes Glaciers may now be irreversibly melting. This is something taking place across the West Antarctic Ice Sheet (WAIS) (Joughin et al., 2014). The mechanism causing such irreversible melting is well understood; glaciologists refer to this as 'basal melt' (Shue, 2018). Basically, while these ice sheets rest on land, the land they rest on (their base) is below sea level. As the water around the glaciers warms it eats away at the ice, and pushes the 'grounding line' – the point at which the ice is grounded to the land – further and further back, thus exposing more and more ice to warmer sea water. Basal melt is a major problem because when the land on which ice sheets rest slopes downward from the grounding line (that is, slopes inland), once basal melt starts it cannot be reversed, leading ultimately to the collapse of the ice sheet. Shue asks us to imagine a scenario in which such a tipping point is crossed in the latter half of the 21st century due to overshoot and reliance upon NETs. The scenario is as follows.

Imagine we pursue a policy route that would stabilize atmospheric concentrations of CO_2eq at 450 ppm by 2100. However, in the next four or five decades, we overshoot the concentration and then rely upon NETs to bring the concentration back down by the end of the century. Shue's well-placed worry is that if we were to rely on such an overshoot scenario, the warming accompanying the temporary overshoot could lead to irreversible ice sheet loss (via basal melt, for example).[8] Shue asks: 'Can we count on nothing like this hypothetical scenario happening? That is the gamble taken by less ambitious mitigation now that relies on later [NETs]' (Shue, 2018: 18).

Ice sheet loss is not the only thing to worry about. There are tipping points all throughout the climate system: plant and animal populations may have acute points of extinction, and melting permafrost may have a precise tipping point, for example. The hypothetical scenario could be run with any of these catastrophic climate consequences in mind. The conclusion Shue reaches from such a thought experiment is that reliance upon NETs amounts to an unjustifiable gamble. This unjustifiable gamble is all-the-more objectionable when it is noted that it is the current generation that can only gain from such a gamble, while future generations can only lose. The upshot from this hypothetical scenario, according to Shue, is that we should not rely upon NETs but should rather increase our mitigation efforts. But for the reasons we highlighted in the previous section – namely, (a) geo-physical limits and (b) the complexity of the socio-political transition needed – relying upon emissions reductions only is far too risky. Not only is it too risky, it is riskier than investing in the development of NETs, unless such investment would have a substantial negative effect on mitigation.[9] Even with NETs in our portfolio, we still run a high risk of heading for catastrophic climate change in the future. This leads us to the conclusion that our climate policy portfolio should be broadened beyond NETs, not narrowed to mitigation only.

Limit warming to less than 2°C by traditional mitigation, NETs, and solar radiation management as a fallback

The concerns of the previous section lead us to consider a more robust suite of policy options, including traditional mitigation, NETs, and a cluster of technologies known as Solar Radiation Management (SRM). SRM technologies vary widely, but they all aim at altering the amount of solar radiation that can be trapped by greenhouse gases. There are some more modest forms of SRM, such as whitewashing human structures. Through painting our roofs a more reflective white (rather than a heat-trapping black), we can reflect more solar radiation back toward space and thus generate a slight global cooling effect. However, the most commonly discussed form of SRM is more extraordinary. Stratospheric aerosol injection (SAI) is a proposal that aims to mimic the natural cooling effect produced by large volcanic eruptions. Through releasing millions of tons of aerosols – for instance, sulfate aerosols – into the upper atmosphere, we could create a kind of sunshade capable of reducing incoming solar radiation by 1–2%. This reduction in incoming solar radiation could have significant cooling effects.

For example, in 1991 the eruption of Mount Pinatubo in the Philippines released somewhere between 10 and 20 million tons of sulfur into the atmosphere (Hulme, 2014). Accompanying this eruption was a temporary drop in global temperatures of 0.5–1°C. It should be noted that the drop in temperature was temporary. Once the aerosols fall from the sky, their reflective effect is eliminated and temperatures rebound. This means that SRM techniques, once imitated, would have to be continued for some time into the future.[10]

Recognizing the difficulties associated with an emissions-reduction-only policy, we think there may be some role for SRM as a potential supplement to a climate policy that both respects the right to sustainable development and stands a reasonable chance of avoiding catastrophic climate change. First, certain SRM techniques could be used to soften some of the well-placed worries about scalability and overshoot highlighted by Lenzi et al. and Shue. Second, the technology could be used to help bridge the gap between scenarios consistent with 2°C and 1.5°C even if we engage in aggressive mitigation and NETs work exactly as planned.

Consider first the role SRM could play in scenarios of overshoot and failed upscaling. If we were to temporarily overshoot a given atmospheric concentration of CO_2eq, and there were to be a correlative temporary increase in temperature that we recognized as risky, we could use SRM to temporarily mask that increase in temperature. Such a use of SRM may not ideal, but could be better than the alternative of allowing perhaps permanent changes to the climate system. Similarly, if we were to aggressively mitigate global emissions with the thought that some of the inevitable emissions will be offset by NETs, we would be in trouble if NETs proved much more difficult to scale up than the models assume. For example, imagine we are only able to build 10,000 BECCS plants by 2050, falling 6,000 shy of the 16,000 that Lenzi et al. predict we need to follow some of the IPCC pathways. SRM could be used as a kind of stop-gap to buy us time until we are able to get the final 6,000 plants up and running. Having SRM as a backup plan seems clearly preferable to abandoning research into such a technology now.

But even if NETs are scalable and even if we are able to deploy them quickly enough to limit climate change to 2°C, there may still be a role for SRM to play. The IPCC Special Report on 1.5°C highlights just how different a world 1.5°C warmer is than a world that is 2°C warmer. Consider what the report says about precipitation from cyclones. It notes that ‘heavy precipitation associated with tropical cyclones is projected to be higher at 2°C compared to 1.5°C global warming’. Mitigating our emissions aggressively and scaling up NETs in way in which we don’t experience any temporary overshoot will be the most difficult social and technological undertaking humanity has ever attempted. And even if we pull off such an undertaking nearly perfectly, we may still find that a world of 2°C has too many catastrophic effects. In such a scenario, SRM could be used to shave off some of the difference between 2°C and 1.5°C, thus assuaging some of the catastrophic climate consequences (Shepherd, 2017).

In sum, there are two reasons to think that there may be some role for SRM to play in future climate policy. First, it could be used to help avoid catastrophic climate consequences in the event that successful NET deployment carries with it a temporary temperature overshoot, or if the technology proves too difficult or too costly to scale up in time for any given emissions mitigation trajectory. But secondly, even if NETs prove viable, SRM could be used to shave off peak warming that may carry with it catastrophic climate consequences.[11]

Given the prospects for SRM to effectively limit warming, and to do so at a non-exorbitant cost (Keith, 2013; Nordhaus, 1994), one might wonder why we shouldn't embed SRM into our climate policy now and simply plan on using it heavily rather than only as a backup strategy. After all, any amount of warming offset by SRM could, in theory, be used to raise the carbon budget, thus allowing developing economies even more time to develop before their emissions would have to decrease. There are myriad reasons not to rely upon SRM as anything other than a back-up climate policy. Here we can only briefly address three categories of the most pressing concerns: (1) SRM does not affect the atmospheric concentration of GHGs; (2) there are known deleterious side-effects of large-scale SRM deployment (so-called *known-unknowns*); (3) there are most likely significant unforeseen deleterious side-effects of SRM (so-called *unknown-unknowns*).[12]

First and foremost, unlike mitigation and NETs, SRM does not directly affect the atmospheric concentration of greenhouse gases.[13] This means that the technology would have to be used consistently (and to greater degrees each year) until emissions peaked and eventually reached zero. Additionally, given that SRM doesn't affect atmospheric GHG concentrations, ocean acidity will continue to rise until concentrations stabilize.

Second, SRM has a number of known deleterious side-effects – so-called 'known-unknowns'. We refer to them as 'known-unknowns' because we know about the potential negative side-effects, but the exact extent of their impacts is unknown. For instance, achieving a given temperature target through SRM could have dramatic effects on precipitation patterns compared to achieving such a temperature target through reduced atmospheric GHG concentrations. As has been pointed out many times now, offsetting the entire 21st century temperature increase with SRM could have devastating effects on the Asian and African monsoons (Robock, 2008). In addition to disrupted precipitation patterns, SRM – specifically SAI of sulfate aerosols – could have negative effects on both atmospheric ozone recovery and surface air quality. While we don't know exactly what these effects would be, we know they would be harmful.

Finally, in addition to the known side-effects of SRM, there will almost certainly be unknown deleterious side-effects as well. Even one of SRM's most outspoken supporters, David Keith, cautions that: 'The largest concern [with SAI] is not the risks we know but rather a sensible fear of the unknown-unknowns that may surprise us' (Keith, 2013: 72). This category of 'unknown-unknowns' is one of the major reasons not to rely upon SRM any more than we might have to. Whatever the unknown negative side-effects are, reason would lead us to believe that they increase the more heavily the technology is relied upon.

For these kinds of reasons, it would be unjustifiable to abandon mitigation and NETs in pursuit of an SRM-only climate change policy. Still, there may be a role for SRM to play in future climate policy, and research into the cluster of technologies should continue. Our motivation for arguing in favor of continued research into SRM is not grounded in some account of naïve technological optimism. Rather, the motivation is grounded in a recognition of the bleak outlook for a policy of mitigation only and the potentially catastrophic risks of relying too heavily or asking too much of NETs. With the amount of both epistemic and moral uncertainty involved in climate change and climate change policy, expanding the set of options available for future generations seems significantly more justifiable.[14]

Conclusion

It is widely agreed that our mitigation pledges are insufficient to limit warming to below 2°C – the goal that international negotiations have set. Since climate change is plenty risky even below 2°C, any plans to allow for additional warming pose reason for concern. We could, of course, get lucky and find that warming is not increased by as much as seems likely given our current emissions path. But hope of getting lucky is not a rational policy path, any more than aiming to get out of debt by playing slot machines is. It would be irresponsible not to assess the range of options before us. They all present problems and any judgment of how best to proceed will have to be an all-things-considered one in which several moral considerations are weighed. We advocate assessing policies in light of, not exclusively, but primarily two main considerations: (1) avoidance of catastrophic consequences, and (2) the right to sustainable development.

Revising the temperature target upwards would seem to unacceptably amplify the risks of catastrophe; it also regressively shifts the costs of climate change on the poor, which threatens to undermine the right to sustainable development. Degrowth would also seem to threaten the right to sustainable development. Increasing mitigation ambition, but pursuing the goal by means of emissions-reductions-only seems highly unlikely to succeed given the geo-physical constraints and the social and political transition required. Such a policy allows a higher risk of failure than is necessary. Supplementing robust mitigation seems far better. This is a reason to believe that policy should incentivize the development of NETs. It is an open question whether these can be developed for use at an appropriate scale, and even if used, whether catastrophe can be avoided. Those concerns argue in favor of pursuing SRM research. Understanding better the effects of SRM and having the technology available might prove useful in avoiding catastrophe and would allow a decision about whether the side-effects could be justified in light of the alternatives avoided. This could expand the choice set of people in the future. Other things being equal, it would be better to leave future generations with a more expansive choice set.[15] Given the delays in the pursuit of robust climate change mitigation, none of the options in front of us are ideal ones. Nonetheless, some are morally preferable to others.

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Notes

1. Article 2 set the objective of preventing 'dangerous anthropogenic interference with the climate system'. And Article 3 paragraph 4 states that 'Parties have a right to, and should, promote sustainable development' (United Nations, 1992).
2. Some people will also object to the anthropocentrism of the principles we employ. We do not deny that there are plausible considerations that do not directly refer to what we owe other human beings but instead to natural values. We do worry, however, that reasonable disagreement about such values will frustrate efforts to arrive at agreement on policy. See Moellendorf (2017).
3. Some have advocated doing away with temperature targets altogether for that reason. Cf. Hulme (2012).
4. We should point out that this analysis is now somewhat outdated. Emissions have continued to rise, meaning that even greater degrowth would be required now compared to back in 2013 when Anderson and Bows-Larkin made their recommendation.
5. Pollin is aware of this, and advocates for investments to reach the 1.5% level across a three-year time horizon. See Pollin (2015: 64).
6. As we've noted, the vast majority of the mitigation scenarios surveyed in the IPCC's AR5 rely on projections that assume a future capacity to remove CO2 from the atmosphere, the employment of negative emissions. There reason to believe that the capacity of NETs to make possible hitting ambitious mitigation targets is significant. Modeling performed by Luderer et al. finds that lowest achievable mitigation target is 0.2–0.3°C less if NETs are used than if not (Luderer et al., 2013).
7. Though, there have been some promising data sets as of late. It seems as though the cost of pulling CO2 out of the atmosphere is cheaper than we have been imagining. See Keith et al. (2018).
8. There is significant uncertainty about the exact relationship between GHG concentrations and warming. For instance, climate sensitivity – the amount of temperature increase associated

with a doubling of atmospheric CO2 concentrations – could be anywhere between 1.7°C and 7.1°C. Current estimates put climate sensitivity around 2.9°C. We flag this simply to note that whether or not a temporary concentration overshoot will carry with it temperature overshoot is difficult to say. This notwithstanding, the worry is far from baseless. See Armour (2017).

9. This is the moral hazard worry we discussed earlier. For a good assessment of the moral hazard argument see Hale (2012).
10. This has raised worries about a so-called *termination shock*. See McKinnon (2019); Parker and Irvine (2018).
11. We should point out that we are not here advocating the use of SRM in an emergency scenario. Rather, the IPCC Special Report leads us to think that there could be catastrophic climate consequences associated even with a warming of 2°C. For a paper looking at why SRM should not be seen as a silver bullet in emergency scenarios, see Sillmann et al. (2015).
12. For a more comprehensive discussion of the reasons not to rely too heavily upon SRM, see Callies (2019).
13. It could indirectly affect the atmospheric concentration, though. For example, we know that higher average global surfaces temperatures are associated with greater melting of permafrost, a process that releases methane (a greenhouse gas). If SRM were to decrease average global temperatures, it would, in theory, decrease methane concentrations in the atmosphere that result from melting permafrost. But, in general, SRM does not have a large impact on atmospheric GHG concentrations.
14. Some might worry that the broad portfolio we endorse would be pragmatically more difficult to effect than a simpler proposal, like that of mitigation only. After all, with mitigation only, it is clear what needs to be done. Whereas, with a hybrid policy like the one we endorse here, there are more points that can be dragged out through endless negotiation. We're sensitive to this worry. Due to considerations of space, we can't fully address it here. But the response would be: if it seemed likely that pursuing a hybrid proposal would lead to endless negotiation and thus more delayed action on climate change, then the calculus would change and support for the hybrid proposal would wane. Of course, negotiating a mitigation only proposal – the proposal that has been pursued so far – has proven to be rather difficult. So, it is tough to say a priori which proposal enjoys an easier path through international negotiations. We thank an anonymous reviewer for bring this point to our attention.
15. This draws upon what Rawls calls 'the principle of postponement'. See Rawls (1999: 360).

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