SYMPOSIUM

# Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change

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Geoengineering, the "deliberate, large-scale manipulation of the planetary environment in order to counteract anthropogenic climate change" (Shepherd et al. 2009, 1), is attracting increasing interest. As well as the Royal Society, various scientific and government organizations have produced reports on the potential and challenge of geoengineering as a potential strategy, alongside mitigation and adaptation, to avoid the vast human and environmental costs that climate change is thought to bring (Blackstock et al. 2009; GAO 2010; Long et al. 2011; Rickels et al. 2011). "Geoengineering" covers a diverse range of proposals conventionally divided into carbon dioxide removal (CDR) proposals and solar radiation management (SRM) proposals. This article argues that "geoengineering" should not be regarded as a third category of response to climate change, but should be disaggregated. Technically, CDR and SRM are quite different and discussing them together under the rubric of geoengineering can give the impression that all the technologies in the two categories of response always raise similar challenges and political issues when this is not necessarily the case. However, CDR and SRM should not be completely subsumed into the preexisting categories of mitigation and adaptation. Instead, they can be regarded as two parts of a five-part continuum of responses to climate change. To make this case, the first section of this article discusses whether geoengineering is distinctive, and the second situates CDR and SRM in relation to other responses to climate change.

## WHAT IS "GEOENGINEERING"?

Although some scholars have argued that certain forms of geoengineering should take priority over mitigation, geoengineering methods are usually proposed as a complement to mitigation and adaptation (e.g., Shepherd et al. 2009, 57). Thus, geoengineering is commonly presented as a third option. However, in almost all reports, this "third option" of geoengineering is swiftly broken down into the two categories of CDR and SRM. This distinction seems straightforward. CDR methods and SRM methods intervene in different stages of the process that results in anthropogenic climate change. More about this issue is presented later, but for now, note that CDR proposals aim at drawing down carbon dioxide from the atmosphere, thus reducing atmospheric greenhouse gas (GHG) concentrations. SRM proposals do nothing about atmospheric GHG concentrations, but instead reduce radiative forcing—the amount of energy absorbed by the atmosphere. Given this difference, it is puzzling why CDR and SRM are brought together and discussed under the name of "geoengineering." What, if anything, do they have in common? And what marks these "geoengineering" responses as different to the other climate responses of mitigation and adaptation?

To examine those two questions, we start with the Royal Society definition of geoengineering, which is similar to many others in that it emphasizes largeness of scale and the deliberate nature of the manipulation.[1] As they are presented as subcategories of geoengineering, it follows that both CDR and SRM are deliberate large-scale manipulations of planetary systems and counteract anthropogenic climate change. Being "large-scale" and "deliberate" does not distinguish CDR or SRM from adaptation or mitigation.[2] If either mitigation or adaptation strategies are to be effective, both have to take place on a very large scale and both need to be, in the main, deliberately planned. The stipulation that CDR and SRM are intended to *counteract* anthropogenic climate change does separate them from adaptation, one definition of which is "[i]nitiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (Parry et al. 2007, 848). Adaptation does not counteract climate change, but reduces the harm done by environmental changes. Mitigation, however, does reduce anthropogenic climate change by reducing atmospheric GHG concentrations. According to the Intergovernmental Panel on Climate Change (IPCC) Working Group III, mitigation is "[t]echnological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic, and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks" (Metz et al. 2007, 818). Indeed, under this definition, which includes enhancing GHG sinks, nothing separates CDR from mitigation.[3] We need to look elsewhere.

One possible way to isolate the differences between concepts is to look at the paradigmatic cases. Consider ocean fertilization (a CDR technique) and injection of sulphate aerosol particles into the stratosphere (an SRM technique). Ocean fertilization is a process where a growth-limiting nutrient, most

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commonly iron but also nitrogen or phosphate, is put into the ocean to increase marine photosynthesis. Sulphate particles, like other aerosols, diffuse sunlight and so reflect more solar radiation back into space, thus preventing solar energy being absorbed by the atmosphere and causing warming. Could there be something about these particular proposals that merits different treatment from mitigation and adaptation measures? Intuitively, these technologies appear to be paradigmatic cases of a much earlier definition of geoengineering.[4] Schelling adduced three features of geoengineering: to count as geoengineering an action must be "global," "deliberate," and "unnatural" (Schelling 1996, 304–5). As noted earlier, deliberateness does not distinguish geoengineering from adaptation and mitigation. What of the other two? Although Schelling gave little explanation, he regarded geoengineering as an intervention in a global system, that is, it takes place in the global commons such as the ocean, or the (higher) atmosphere.[5] As such, it cannot be contained within a particular area.[6] These kinds of intervention raise particular governance challenges. It is not clear, however, that "being global" is sufficient to unite the categories of CDR and SRM, nor to distinguish them from mitigation and/or adaptation. First, many types of proposals conventionally discussed under CDR and SRM are capable of being territorially contained, if by this we mean that the techniques operate on a specific site, such as an enhanced weathering plant, or a site where afforestation takes place. The *effects* of these activities, however, are always global. This is also true of mitigation activities: there might be a discrete site of activity, but the effects have a global impact. Moreover, mitigation, CDR, and SRM all raise questions of who has the right to intervene or use the global commons and to what degree? Behind the debates on mitigation is the question of who has a right to use the Earth's common systems to absorb the GHGs emitted for creating energy. Mitigation policies attempt to regulate these interventions in the global climate system. CDR will do the same. SRM is another form of intervention in the global climate system (to ameliorate, in part, the effects of the previous ones). Nor are adaptive responses inevitably "local." Some adaptation measures, such as changes in use of rivers and lakes, raise transboundary issues. Moreover, migration, as an adaptive measure, takes place across national boundaries, necessarily so, if small island states are eventually submerged. While these adaptation measures might be regional rather than fully global, it is not clear that either the site or the effects of adaptation can be territorially contained.

Schelling's final criterion of "unnatural" is raised in debates about geoengineering as a public moral concern. In deliberative workshops held in the UK, technologies perceived as "(more) natural" had stronger public support (e.g., NERC 2010, 32–33). (Seemingly related is the objection that geoengineering is hubristic.[7]) Again, not all potential forms of technology that are usually regarded as CDR or SRM are regarded as unnatural. But perhaps, as Aaron Ray suggests, the criterion of naturalness should be used as a defining feature of geoengineering. Doing so would narrow down the category of technologies that are usually considered to be geoengineering (Ray 2010). Some forms of CDR and SRM can be considered unnatural, and those that are should count as geoengineering.

Even if there is agreement about what counts as "natural" and "unnatural," this move does not help. "Unnaturalness" is not a feature shared by some CDR and some SRM, but not by mitigation or adaptation. Mitigation measures require large changes in infrastructure and development of carbon-free technologies, a human, rather than a "natural" process. Changes in infrastructure, technology, and the use of new resources is also a part of adaptation. In particular, both mitigation and adaptation may use unnatural technologies, or raise issues of hubris. Nuclear power is likely to be part of mitigation strategies in many states. Adaptation could involve the increased use of genetically modified crops. Both of these measures can be regarded as "unnatural" and seen as embodying hubristic attitudes as much as ocean fertilization or sulphate particle injection.

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Although an exhaustive analysis has not been possible, the upshot of this discussion is that criteria such as "deliberate," "large-scale," or "unnatural" do not distinguish geoengineering, either CDR or SRM, from mitigation or adaptation. The next section suggests that CDR and particularly SRM differ from mitigation and adaptation according to the place at which either intervenes in the process between emitting GHGs and experiencing the impacts of climate change. It goes on to develop a five-fold typology of responses to climate change.

## FIVE RESPONSES TO CLIMATE CHANGE

As noted earlier, mitigation refers to any set of actions intended to reduce humanity's output of greenhouse gases, either by curbing them at their source, for example, by switching to noncarbon fuels or by increasing the capacities of carbon sinks—systems that absorb carbon dioxide. Mitigation is a preventative measure. Whereas mitigation deals with the cause of climate change, adaptation deals with its effects. That is, the aim of adaptation is to reduce the harmful impacts that a changed climate is likely to have on people's lives—adaptation takes the "danger" out of "dangerous climate change." Thus, adaptation responds to environmental changes; it does not prevent them.

*Figure 1*

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|---|---|---|---|---|---|
| **Aim** | **Avoiding climate change** | | | **Avoiding "dangerous" climate change** | **Responding to dangerous climate change** |
| | Avoiding a given level of atmospheric GHG concentration | | Avoiding global average temperature increases | Ensuring that rising temperatures do not impact upon core interests | Providing redress for injuries to core interests |
| **Strategy** | **Mitigation**<br>Reducing GHG emissions | **CDR**<br>Drawing GHGs out of the atmosphere | **SRM**<br>Increasing albedo | **Adaptation**<br>Improved irrigation, flood defences, protection against disease | **Rectification**<br>Financial compensation, symbolic reparation. |

Perhaps new CDR techniques constitute potential forms of mitigation. The reason for this is, quite simply, conventional definitions of mitigation, such as the one quoted earlier from the IPCC hold that mitigation can be achieved *either by reducing GHG emissions, or by enhancing GHG sinks*. Note, the purpose of CDR techniques is to increase the overall sink capacity. These techniques do nothing to alter the flow of $CO_2$ into the atmosphere but directly affect the stocks of $CO_2$ that already exist. Some of these do so by fairly familiar means, such as afforestation, previously described as mitigation (IPCC 2007, 10). More novel techniques include the various forms of enhanced weathering and ocean fertilization, all of which capitalize on elements of the carbon cycle. Air capture techniques use chemical processes to create new forms of sink. Therefore, we might describe the analytical difference between mitigation and CDR as follows:

1. Mitigation refers to activities that *either* reduce the flows of $CO_2$ and other GHGs into the atmosphere *or* increase sinks.
2. CDR refers to activities which increase sinks.

CDR thus is a subset of mitigation. However, specifying CDR as a separate category has some advantages.[8] One reason is that mitigation is often discussed solely in terms of reducing GHG emissions. Emphasising the creation of sinks as a separate category might make this option more prominent. Specifying CDR as a separate category also allows us to distinguish two separate stages in the process of avoiding dangerous anthropogenic interference. First, we might reduce initial inputs of GHGs. Second, we might ensure that outputs are increased to balance or exceed the initial inputs. An analogy might help.[9]

Imagine a man with high blood pressure because he is overweight. Accordingly, he is at greater risk from a heart attack. He might address this situation in different ways. First by dieting—reducing inputs to the system. Second, he could continue his previous eating habits, but embark on a vigorous exercise program. Both of these strategies address the cause of the problem but at two different stages.

Now consider the relationship between SRM and adaptation. If CDR is technically a subset of mitigation, but worth highlighting, might SRM be a subset of adaptation? The answer to this depends on whether dangerous anthropogenic interference, or dangerous *climate change* is taken as the referent.[10] When dangerous anthropogenic *interference* (increasing atmospheric GHG concentrations) is taken as the referent, SRM is responsive. When dangerous climate change is taken as the referent concept, as it increasingly is, SRM techniques are preventative.[11] They attempt to prevent climate change by ensuring that global temperatures remain relatively constant regardless of the changes in the atmospheric concentrations of GHGs.[12] This approach is different from trying to keep global temperatures down by reducing GHG concentrations. It is also different from allowing the temperature to increase but trying to ensure that human life can continue, which is the aim of adaptation. Recall our overweight man. As well as (first) dieting and (second) exercising, which address the cause of the problem, he might respond in two additional ways. He might take warfarin to reduce the chances of blood clots or other medication. Or, he might take extra time for walking, avoid stressful situations, or otherwise adjust his behavior so that the high blood pressure does not lead to a heart attack. There is something materially different between these latter two kinds of response. SRM is the equivalent of taking warfarin. Adaptation is the equivalent of living with the symptoms, but minimizing their affect on one's overall quality of life in terms of core interests. As such, SRM constitutes an analytically discrete category and is the third category of response to climate change. Adaptation is the fourth.

For completeness, we can add the fifth category: rectification. Rectification includes financial compensation and symbolic measures such as apology. It is appropriate if mitigation, conceived narrowly in terms of CDR, SRM, and adaptation are not pursued, or are unsuccessful.[13] See figure 1.

## CONCLUSION

Responses to climate change can be differentiated by where they occur in the process between emitting GHGs and the loss of human wellbeing. Mitigation policies are directed at avoiding dangerous anthropogenic interference. Either the GHGs are not emitted in the first place (the flow of emissions is reduced) or the stocks are reduced by CDR techniques. The distinction between CDR and mitigation is not watertight. However, it is important to distinguish whether a response is aimed at reducing emissions at their source, or ensuring, by later action, that atmospheric concentrations do not continue to rise. Mitigation, as usually conceived, does not counter the climatic effects of past GHG emissions. CDR technologies, if successful, enable retrospective action on levels of GHG concentrations.

SRM technologies do not affect atmospheric GHG concentrations. They *prevent climate change* (or at least one key part of it) by keeping global temperatures stable, despite the increased GHG concentration. Adaptation does not prevent climate change but ensures that core interests continue to be met in a warmed world. It takes the "danger" out of dangerous climate change, rather than trying to prevent the change. Thus, SRM is distinct from adaptation. Finally, rectification neither prevents climate change nor prevents key interests being compromised. It aims to "make up" for the loss of interests sustained.

This five-stage continuum of responses to climate change is preferable to shoe-horning CDR and SRM into the existing categories of mitigation and adaptation and to grouping CDR and SRM together under the rubric of geoengineering. Concepts cease to be helpful when they are too broad, or too vague, and geoengineering is one such concept. Let future research and debate cease to be about "geoengineering" and instead focus on the specific features of proposed technologies, and the appropriate mix of emission reductions, CDR, SRM, adaptation, and rectification.

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**NOTES**

1. For an overview of the main definitions of geoengineering, see Bellamy et al. (2012, 5).
2. The intentional nature of these measures does, however, serve to differentiate intentional interference with the Earth's climate system from the unintentional interference that has resulted in anthropogenic climate change.
3. As we shall see later, it might be useful to distinguish mitigation and CDR for practical purposes.
4. The earliest use of the term "geoengineering" in relation to climate change is usually attributed to Cesare Marchetti (1977). Marchetti does not provide a definition of geoengineering; indeed, the term appears only in the title of his article and not in the main text. As far as I know, the first attempt providing a substantive definition of geoengineering appeared in a report by the National Academy of Sciences (NAS). According to the NAS, geoengineering is the "large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric chemistry" (NAS 1992, 433).
5. This is assuming for the sake of argument that the idea of the ocean or atmosphere as a "global commons" is defensible. If it is not then the attempt to separate geoengineering on this basis will fail.
6. Here my interpretation of Schelling follows that of Aaron Ray. Ray accordingly argues that land-based biomass/energy and sequestration technologies and enhanced weathering should not count as geoengineering because they can be sited on the territory of a nation-state (2010, 38). This view is contrary to the reports cited earlier, which count the above activities as examples of geoengineering and Ray does not say why he thinks his classification is an improvement.
7. A participant at a seminar suggested that geoengineering technologies are those which embody the wrong attitude toward nature; they are those which are hubristic. Both the charges of "unnaturalness" and hubris seem to be based on the assumption that humans should seek to live in accordance with nature (Jamieson 1996), rather than extensively modifying it for their own purposes.
8. Thank you to Luke Tomlinson for raising the question of whether mitigation and CDR should be regarded as completely distinct.
9. Thank you to Ed Page for suggesting the analogy used here.
10. Dangerous anthropogenic interference is related to, but analytically distinct from, the concept of dangerous climate change. Whereas dangerous climate change refers to the extent and type of impacts expected as a result of changes in global temperatures, dangerous anthropogenic interference can be specified in terms of GHG concentrations in the atmosphere. For any level of GHG concentration, there is an attendant probability of a given level of temperature increase. So, dangerous anthropogenic interference can be defined as engendering an unacceptable risk of dangerous climate change. As a normative concept, the idea of dangerous climate change is predicated on a prior idea of what is important (to human beings). Temperature increases that pose a threat to core human interests can be considered "dangerous." In the policy world, there is increasing convergence that the maximum acceptable temperature increase is 2°C above preindustrial levels. However, this target is based on predictions of adaptive capacity. If prospects for adaptation turn out to be lower than currently predicted, this would mean that core human interests would be compromised at lower temperature rises. In such a case, "dangerous climate change" would occur before the 2°C threshold was reached. Dangerous climate change, as used here, should not be confused with the perhaps even more problematic concept of a "climate emergency."
11. It might be the case that some forms of SRM might also be used after a certain amount of temperature increase, to bring temperatures down to a more desirable level, or to prevent further temperature increases. Even if this is the case, the aim of SRM is still to prevent sustained temperature increases.
12. SRM methods cannot address all forms of climatic change, such as ocean acidification. I leave this issue to one side.
13. The numbering of the categories of response does not imply an ordering for climate policy priorities.

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