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## The Ethics of Engineering the Climate\*

Interest in the idea of “climate engineering” has grown significantly in the scientific community during the last decade. Within that community there is growing pessimism that action on anthropogenic climate change will be sufficient to limit the average global temperature increase to 2° Celsius without significant technological development. Indeed, under the Intergovernmental Panel on Climate Change’s RCP 2.6 scenario, where global mean temperatures are stabilised below 2°C, it is assumed that bio-energy carbon capture and sequestration technologies have been successfully developed and implemented.

This is an example of a carbon-dioxide removal technology and as such, is often considered to be an example of a climate engineering technology. Other carbon-dioxide removal technologies include increasing direct air capture, enhanced weathering, increasing ocean alkalinity and ocean fertilization. The term climate engineering is also used to refer to technologies that aim to counteract anthropogenic climate change by increasing albedo so as to reflect more solar energy and thus reduce temperature increases. “Solar radiation management” techniques include settlement and crop brightening, marine cloud brightening, and stratospheric sulphate aerosol injection. A further possibility might consist in increasing outgoing thermal radiation.

In the decade following the publication of Crutzen’s (2006) article, which was widely credited with bringing the debate into the scientific mainstream, we have seen many publications investigating natural science and engineering issues, opinion pieces (e.g. Keith et al. 2010), and reports from governmental and science policy institutions (e.g. Shepherd et al 2009, Rickels et al. 2011, NAS2014a&b, EuTRACE 2015). This “1<sup>st</sup> wave” of climate engineering discourse effectively began in the mid-2000s and has lasted, roughly, up until the present. It exhibits two main features. First, as a matter of necessity, the discussions were largely speculative, due to the many uncertainties remaining in climate science, and also because a fully-fledged climate engineering technology is not yet proven feasible for large scale deployment. Second, the vast majority of participants in the discourse, regardless of their academic discipline acknowledged that the development of climate engineering technologies is not only a matter for natural scientists and engineers. The interdisciplinary reports and assessments that marked the first wave took broadly similar formats and propounded similar messages, namely that research into climate engineering technologies ought to continue, and to have a higher priority in terms of research funding and institutional support than hitherto, and that “research” should be taken to include research in social sciences, law and the humanities. The other key recommendation was for public involvement (of various kinds) in the research and development process.

The first wave was both necessary and productive in terms of getting climate engineering technologies recognized as potential elements of societal responses to climate change.

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However, it exhibited a number of drawbacks. Two, in our view, are particularly important. First, the term “climate engineering” and its synonyms gave an unwarranted veneer of unity over a set of heterogeneous technologies, whereas different normative issues arise when talking about different technologies. Second, despite the fact that interest in climate engineering technologies has arisen largely because of the slow progress in mitigation, many of the first wave discussions failed to take the wider context of global climate change and global climate change politics into account. For example, the argument that sulphate aerosol injections could avert a “climate emergency” (Caldeira and Keith 2010) did not acknowledge the difficulties surrounding the determination as well as declaration of such an emergency, and claims about ‘optimal’ responses to climate change involving climate engineering technologies largely ignored over 20 years of debate in climate economics and ethics (e.g., Spash 1994a, b, 2002, 2007; Munda 1996; Betz 2006; Hampicke 2011).

In terms of the contribution from moral and political philosophy, most of the early contributions surveyed the terrain and mapped either the overall debate (e.g. Tuana et al. 2012; Svoboda 2012; Betz and Cacean 2012) or specific arguments (e.g. Gardiner 2010, 2011; Preston 2011). This Special Issue seeks to deepen the debate and begin what we might call the “second wave” of ethical debate on climate engineering. This second wave might be characterized in terms of (1) talking about specific technologies rather than the general term of “climate engineering”; (2) offering detailed analysis of specific problems faced by particular technologies; (3) integrating discussions about these technologies with those concerning action upon mitigation, adaptation, loss and damage, and perhaps other issues of global politics (issues regularly discussed in the pages of this journal; see for example, Light and Taraska, Hartzell-Nicholls, Mulligan, Hale, Lee and Hermans, and Shockley in a 2014 Special Issue on ‘Adapting to a Perilous Planet’); and (4) offer substantive conclusions and recommendations, which can then be debated in various fora. The choice of contributions *as a whole* contains the four main elements of a second wave approach. They are ordered according to where they occur on an “imaginative climate engineering timeline” of contemplation, research, deployment and cessation (Preston 2012).

Michael Keary explores a general issue relevant during the contemplation of different climate engineering options: an assumption of technological change modelling, a form of technological optimism. By analyzing the role of facilitative innovations and system-building for the development and dissemination of new technologies from the Social Construction of Technology viewpoint, he highlights important issues that will appear in all sorts of technological assessments and deliberations about policy choice. Keary also recommends that priority be given to options emphasizing the need to reorganize current production and consumption patterns rather than thinking about solving the problem by technological change and the deployment of techno-fixes.

Though the trade-offs investigated by Christian Baatz are also worth considering during the “contemplation stage”, they are more pressing during research and development of climate engineering technologies. He discusses to what extent solar radiation management technologies such as sulphate aerosol injections and possibly marine cloud brightening might reduce mitigation efforts and why this is relevant for research and possibly deployment

decisions. Baatz concludes that there are serious trade-off risks and that this provides a weighty reason to adopt anti-trade-off measures.

Toby Svoboda's contribution relates the climate engineering debate to alternative options that have been discussed at length under the heading of climate ethics. He compares drawbacks of the most prominent climate engineering technology to date, namely the injection of sulphate aerosols in the upper atmosphere, with drawbacks of a mitigation/adaptation approach. Svoboda concludes that certain forms of aerosol engineering may offer a more just response to the climate change problem than the abandonment of the technology; for example if it is used in a limited way in order to protect the interests of the poor.

Harald Stelzer and Fabian Schuppert offer a framework for normatively assessing technology development and implementation decisions. After briefly rehearsing consequentialist responses to the issue of risk the authors develop a multi-dimensional consequentialist framework based on wellbeing, fairness and probability, which they claim can help assess the deontic status of technologies within in the context of climate change policy options. They show this by a case study comparing stratospheric solar radiation management to different other climate change policies. However, although their assessment clearly favours aggressive mitigation compared to all other options, they refrain from recommending a moratorium on research.

Finally, Christopher Preston argues that decisions about whether to develop any climate engineering technology should take into account the ease with which its usage, once started, may be stopped. He calls this the "cessation requirement". Preston emphasizes that for this it is most important to take into account the social context in which the technologies are used. He argues that carbon-dioxide removal technologies face fewer "social barriers" to cessation than solar radiation management technologies, but even in the latter case, the barriers remain significant.

Taken together, we hope that these pieces will stimulate deeper reflection on the place of climate engineering technologies when considering how to respond to climate change.

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