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'Opening up' geoengineering appraisal: Multi-Criteria Mapping of options for tackling climate change

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ABSTRACT

Concerted efforts have begun to appraise deliberate, large-scale interventions in the Earth's climate system known as 'geoengineering' in order to provide critical decision support to policy makers around the world. To date geoengineering appraisals have employed narrowly framed inputs (such as context, options, methods and criteria) and 'closed' output reflexivity often amounting to unitary and prescriptive policy recommendations. For the first time, in this paper we begin to address these limitations by 'opening up' appraisal inputs and outputs to a wider diversity of framings, knowledges and future pathways. We use a Multi-Criteria Mapping methodology to appraise carbon and solar geoengineering proposals alongside a range of other options for responding to climate change with a select but diverse group of experts and stakeholders. Overall option rankings are found to vary considerably between participant perspectives and criteria. Despite these differences, the ranks of geoengineering proposals are most often lower than options for mitigating climate change (including voluntary behaviour change and low carbon technologies). The performance of all options is beset by uncertainty, albeit to differing degrees, and it can often be seen that better performing options are outperformed under their pessimistic scores by poorer performing options under their optimistic scores. Several findings contrast with those of other published appraisals. In particular, where stratospheric aerosol injection has previously outperformed other geoengineering options, when assessed against a broader diversity of criteria (spanning all the identified criteria groups) and other options for responding to climate change it performs relatively poorly. We end by briefly exploring the implications of our analysis for geoengineering technologies, their governance, and appraisal.

1. Introduction

Resurgent interest in the prospect for 'geoengineering' the climate follows a long history of desire to bring the forces of nature under human control (Fleming, 2010). Once believed to be powers that only the Gods of ancient mythologies and religions could bestow, the ideas of climate control are now thought to be within the reaches of science and technology. Research into climate modification reached its height during the Cold War, where plans to 'optimise' climate (e.g. Rusin and Flit, 1960) were succeeded by experiments to weaponize weather during the Vietnam War (Fleming, 2006). Today such research is concerned with tackling anthropogenic climate change through geoengineering, an idea that gained prominence in 2006 when Nobel laureate Paul Crutzen, frustrated by insufficient mitigation efforts, proposed artificially enhancing the Earth's albedo through stratospheric aerosol injection (Crutzen, 2006). Geoengineering comprises a disparate collection of deliberate, large-scale interventions in the Earth's climate system that can broadly be divided amongst 'carbon geoengineering' proposals which seek to remove and sequester atmospheric CO_2, and 'solar geoengineering' proposals which seek to increase the reflection of sunlight away from the Earth (Royal Society, 2009). Together with the risk of climate 'emergencies' and other normative rationales for geoengineering, concerted efforts have begun to appraise the pros and cons of these different proposals in order to provide critical decision support to policy makers around the world.

A recent review of existing geoengineering appraisals reveals that they hold a number of significant limitations relating to their

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narrowly framed inputs and 'closed' output reflexivity (Bellamy et al., 2012). Appraisals of geoengineering have been conditioned by narrow problem framings, in which particular issues, such as the predominant 'insufficient mitigation' (e.g. Crutzen, 2006) and 'climate emergency' (e.g. Blackstock et al., 2009) frames, exclude alternative problem definitions. Concurrently, appraisals have almost exclusively focused on assessing single geoengineering options (e.g. Keith et al., 2005; Lampitt et al., 2008; Robock et al., 2009) or on developing internal comparisons between geoengineering options (e.g. Keith, 2000; Lenton and Vaughan, 2009; NERC, 2010). Existing appraisals have thus consistently isolated geoengineering proposals from their decision context by omitting the wider portfolio of options for responding to climate change, spanning mitigation and adaptation.

Methods for appraising geoengineering have most often closed down around 'expert-analytic' procedures such as computer modelling (e.g. Moore et al., 2010), cost–benefit analysis (e.g. Bickel and Lane, 2009), expert review (e.g. Robock, 2008) and multi-criteria analysis (e.g. Boyd, 2008), and employed technical criteria such as those spanning efficacy, feasibility and economics (Bellamy et al., 2012). While such methods make a vital contribution to the appraisal of technical issues and in building an essential knowledge-base for geoengineering governance, they do not adequately respond to the 'post-normal' scientific context in which geoengineering resides (Funtowicz and Ravetz, 1993). The high uncertainties and high stakes of climate change, heightened further by its intentional manipulation through geoengineering, limit the propriety of 'normal' basic or applied science. These uncertainties and stakes demand that appraisals include axiological factors, not only from experts but from all those with a stake in the issue, from an 'extended peer community'.

Inputs to appraisals of geoengineering, such as perspectives, procedures, options and criteria, have been found to be narrow in focus (Bellamy et al., 2012). These often unacknowledged instrumental framings can exert significant power upon appraisal outputs, 'closing down' around those particular knowledges and marginalising the true diversity of perspectives that bear upon the issue (Stirling, 2008). Following on from this, there has been a tendency for the outputs, such as findings, conclusions and recommendations, from many of the aforementioned appraisals of geoengineering to have been closed down as well. This can lead to unitary and prescriptive decision support, and overlook the diversity and sensitivities of decision pathways that are available, possible or imaginable (Stirling et al., 2007).

Ultimately these contextual, methodological and un-reflexive instrumental framings have amounted to the closing down upon particular values and assumptions, whilst excluding the diversity of others. In many cases, it has led to conclusions that close down upon particular options, principally stratospheric aerosol injection: a controversial solar geoengineering proposal to inject reflective sulphate particles into the stratosphere and cool the Earth (e.g. Keith, 2000; Lenton and Vaughan, 2009; Izrael et al., 2009). Closure in 'upstream' technologies such as geoengineering can risk premature 'lock-in' and conflict between divergent values and interests, as was previously the case with the proposed commercialisation of genetically modified (GM) crops (Wilsdon and Willis, 2004).

Methods of appraisal exist which actively seek to address issues of closure such as those pervading appraisals of geoengineering, by 'opening up' to the wider diversity of framing conditions and perspectives that permeate the issue. These include, but are not limited to, scenario workshops (Ogilvie, 2002), Q-method (McKeown and Thomas, 1988), Stakeholder Decision Analysis (Burgess, 2000) and Deliberative Mapping (Burgess et al., 2007). This article presents the findings of research using another such innovative methodology, Multi-Criteria Mapping (MCM) (Stirling, 1997; Stirling and Mayer, 2001), a multi-criteria option appraisal method designed to map the diversity of contrasting perspectives bearing upon complex policy issues.

This research on geoengineering builds on the successful development and application of MCM in the anticipatory appraisal of analogous complex and uncertain emerging technologies, including agricultural biotechnologies (Stirling and Mayer, 2001), medical health technologies (Davies et al., 2003), and energy-related technologies (Stirling, 1994; Chilvers and Burgess, 2008). Whilst acknowledging other possible framings, such as climate optimisation or weaponization the research sought to appraise carbon and solar geoengineering proposals using the broader framing of 'responding to climate change' and the diverse portfolio of alternative options it opens up. This was done with a range of specialist and stakeholder perspectives, as part of a wider research project also involving public participation.

2. Methods

As with other multi-criteria methods, the MCM method comprises four stages: (1) developing a set of options to appraise; (2) characterising a range of criteria against which to assess those options; (3) scoring the relative performance of the options against those criteria; and (4) assigning a weighting to each criterion to indicate their relative importance. The procedural methods of the MCM method are explained more fully in Stirling and Mayer (2001), but aspects specific to this study demand detailed discussion here.

2.1. Framing

In recognising the narrow contextual limitations of earlier appraisals of geoengineering, the study adopted an open problem framing and broad issue context. Rather than defining the 'problem' as a leading one of 'insufficient mitigation' or the risk of a 'climate emergency', for example, it was framed as an exercise in 'responding to [global] climate change' which allowed for a diversity of perspectives to bear upon it. This problem framing extended to the adopted issue context, where geoengineering proposals were presented alongside alternative options for responding to climate change; as well as allowing for the introduction of additional options defined by the participants themselves.

Options for responding to climate change can be broadly divided amongst mitigation, adaptation and geoengineering strategies. The Intergovernmental Panel on Climate Change (IPCC) defines *mitigation* as 'implementing policies to reduce greenhouse gas emissions and enhance sinks' (IPCC, 2007, p. 84). The inclusion of sink enhancement in this definition reflects some ambiguity relating to the categorisation of carbon geoengineering proposals, some of which share this aim. In this study we disaggregate them and restrict mitigation to mean options available to reduce greenhouse gas emissions, spanning energy conservation/efficiency and low carbon energy production.

The IPCC defines *adaptation* as '...measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects' (IPCC, 2007, p. 76). The objectives of adaptation, however, are fundamentally different to those of geoengineering and mitigation. Whilst those latter strategies seek to avoid or lessen climate change itself, adaptation seeks to address its impacts. Adaptation options are responses to temporally and spatially specific impacts, experienced as weather events, and therefore cannot be presented alongside geoengineering and mitigation options at a meaningful resolution. For example, stratospheric aerosol injection and offshore wind energy both seek to tackle or avoid climate change, but constructing flood defences does not. Whilst adaptation strategies could not be meaningfully included in the study as discrete options to appraise, the concept of