Examining framings of geoengineering using Q methodology

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Examining framings of geoengineering using Q methodology

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Abstract

Despite (or perhaps reflecting) widespread awareness of its ambiguity, the term 'geoengineering' has in recent years become massively more prominent. Academic, policy and civil society circles routinely use this term to describe, support or oppose a diverse range of techniques and ideas. This study aims to contribute to understandings of ways in which variously envisaged approaches to 'geoengineering' of the global climate are currently being framed. It asks not only about variously viewed implications of geoengineering itself, but also what these diverse framings can reveal about wider politics in contemporary debates around climate change, science and technology. The paper applies Q methodology to analyse geoengineering as a subjective discursive construct, the bounds of which are continually negotiated and contested. 35 participants from a variety of disciplinary and institutional backgrounds in the UK, US, Canada and Japan undertook a 'Q sort' of 48 opinion statements about geoengineering between December 2012 and February 2013. Four distinctive framings emerged from this analysis, labelled: *'At the very least we need more research'; 'We are the planetary maintenance engineers'; 'Geoengineering is a political project';* and *'Let's focus on Carbon.'* Results indicate a strong polarity around divergently-construed pros and cons of geoengineering as a whole – underscoring the political salience of this term. But additional axes of difference suggest a more nuanced picture than straightforward pro/anti positioning. The ambiguity of the term is argued to offer interpretive flexibility for articulating diverse interests within and across contending framings. The paper questions whether increasing terminological precision will necessarily facilitate greater clarity in governance discussions or public engagement, and argues that the merits of any given form of precision will depend on particular framings. Much ambiguity in this area may thus be irreducible, and hence the challenge lies rather in realising the wider implications of the political pluralities this reveals.

Introduction

This paper explores divergent societal framings of variously-envisaged approaches to 'geoengineering' of the global climate (henceforth geoengineering). A diverse array of technologies are commonly referred to as geoengineering, including those that have been collectively labelled as solar

radiation management methods (such as stratospheric aerosol injection and marine cloud brightening), and those referred to as carbon dioxide removal methods (such as ocean iron fertilization, or direct air capture) (Shepherd et al. 2009). Although the term geoengineering has become increasingly prominent in discussions of these approaches in scientific, policy, and civil society circles, there is evidence of a growing sense that the label itself may be so broad and ambiguous as to be unhelpful, or even incoherent. Thus the recent report from the IPCC 'expert meeting on geoengineering' draws attention to the 'fuzzy' boundary between geoengineering and other approaches to dealing with climate change, and suggests that 'because of the longstanding ambiguity surrounding the term geoengineering … the individual methods discussed might be referred to more specifically' (Edenhofer et al. 2012, p.3). This refrain about the need to look at different technologies and approaches separately runs through many other reports on geoengineering, and yet many of them (like the IPCC report) retain the word geoengineering in their titles (Shepherd et al. 2009; GAO 2010). In one such report by the US think tank, the Bipartisan Policy Centre (Long et al. 2011), debates around whether the term geoengineering 'was too imprecise…[or] too controversial' (Sarewitz 2011, p.7), actually resulted in the appearance of the additional (equally imprecise) term 'climate remediation' being used alongside geoengineering in the title. Given the widespread awareness of the ambiguity of the term, and the difficulties this poses for meaningful governance, is it the case that the term geoengineering can be said to have simply outgrown its usefulness? Or is it that, as has been argued to be the case for terms such as 'sustainability' or 'sustainable development' (Baker et al. 1997) it is the very ambiguity of the terms that might make them particularly useful to certain actors and give them a resilience they might not otherwise have had?

In this study rather than seeing ambiguity as 'a linguistic veil which can be lifted to reveal the truth' (Rydin 1999, p.468), and attempting to remove it by carrying out our own boundary work to define a sub-set of technologies or approaches as our object of study, we embrace the ambiguity of the term geoengineering. This study is thus distinct from previous work on frames and framing of geoengineering, much of which starts by offering a definition of geoengineering as the object of study (Sikka 2012; Luokkanen, Huttunen & Hildén 2013; Huttunen & Mikael Hilden 2012; Scholte et al. 2013; Nerlich & Jaspal 2012).[1] This paper takes a fundamentally different approach: rather than treating geoengineering as an object, a 'novel controversial technology' (Luokkanen, Huttunen & Hildén 2013), or even a set of technologies about which there exists an array of sometimes conflicting opinions, or for which there is support or opposition, this study treats geoengineering as a discursive phenomenon, the bounds of which are continually being negotiated. This is in

[1] An exception might be the work of Bellamy et al.(Bellamy et al. 2012) who do explicitly explore the ambiguity in the term at the outset of their paper, however there is a subsequent attempt to minimise this ambiguity by adopting a singular definition (*ibid* p. 7).

line with insights from post-positivist policy analysts such as Hajer who have drawn attention to the fact that environmental conflict should not be understood as 'a conflict over a pre-defined unequivocal problem with competing actors pro and con,' but rather should be seen as 'a complex and continuous struggle over the definition and meaning of the environmental problem itself' (M. A. Hajer 1997, p.14). Focusing analytical attention on the inherently ambiguous, undifferentiated category 'geoengineering' (a term that has been referred to as a 'quasi-stable meta-label' (Porter & Hulme 2013, p.3)), is argued to be the best way to identify (rather than impose) the most significant axes for distinction, as these relate to key differences in divergent perspectives.

Rather than working to remove ambiguity from the term geoengineering then, this study shifts the focus to an exploration of the kinds of work it does (in spite of, or because of the ambiguities within it), the boundary work it prompts and the tensions and ambivalences it inspires and reveals. We ask what these can reveal about the kinds of politics at work in contemporary debates around climate change, science and technology.

Framing geoengineering

There is a small but growing body of social scientific literature examining discourses and framing of geoengineering, including work examining framings of geoengineering in the media (Porter & Hulme 2013; Scholte et al. 2013; Luokkanen, Huttunen, Hildén, et al. 2013), academic literature (Bellamy et al. 2012; Huttunen & Mikael Hilden 2012), work examining the use of metaphor in framings of geoengineering (Nerlich & Jaspal 2012), or examining the framings within particular influential texts (Gardiner 2011). While a number of common themes (for example the importance of 'climate emergency' as a framing device) emerge from this work, a diversity of findings have been presented regarding the relative openness or otherwise of the discourse around geoengineering, or the relative importance of strategic framing to the issue. Given that the term is arguably still unfamiliar to many people, some have argued that the 'first impression, frame, and narrative has yet to be set' (Leiserowitz 2010, cited by Buck 2013), or suggested that there is a *need* for more active and strategic framing of the issue by scientists in particular ways (Buck 2013). On the other hand others have suggested that the way that appraisals of geoengineering options have been carried out to date, provide evidence of a premature 'closing down' around particular 'sets of values and assumptions with respect to the instrumental framing effects of contexts, methods and criteria and options' (Bellamy et al. 2012, p.28), or cite evidence from analysis of the metaphors used to describe geoengineering as indicative of 'restrictions in the interpretative flexibility' of the term (Luokkanen, Huttunen & Hildén 2013). Sikka takes a particularly strong view of the strategic nature of the framing of geoengineering to date, arguing that 'special interests, including private corporations, conservative think tanks and scientists affiliated with both have drawn on a variety of discursive frames to limit, shape and mould the current debate

surrounding geoengineering' (Sikka 2012, p.173). Conversely others have drawn evidence from an analysis of the changing frames of geoengineering apparent in English speaking newspapers in recent years, to argue that there is evidence of a progressive 'opening up' of the debate around geoengineering (Scholte et al. 2013).

This study falls broadly under the description of a frame-reflective analysis outlined by Schon and Rein (Schön & Rein 1995), and complements and builds upon the corpus of work on framing of geoengineering by bringing a distinctive focus on the ambiguity of the term, as outlined above. Within this study, frames are understood as 'schemata of interpretation' (Goffman 1974, p.21), or narratives of understanding that 'help to render events meaningful and thereby function to organize experience and guide action' (Benford & Snow 2000, p.614). Crucially, frames have both ontological and normative dimensions in that they 'link causal accounts of policy problems to particular proposals for action, and so link accounts of 'is' and 'ought' (Rein and Schon cited in Fischer and Forester 1993, p. 11). Hoppe (1999) emphasises that frames are *necessary* for judgement and action, acting as 'a sort of mental grappling hook' (p.207) to enable people to make sense of and act on a given situation. Through selectively emphasizing certain facets of a given issue over others, and linking interpretation with action, frames in and of themselves can be understood to perform particular functions (c.f. Entman 2004). However there may be a distinction made between the use of the verb framing and the resulting frames or framings as nouns, with the former denoting 'an active processual phenomenon that implies agency and contention at the level of reality construction'(Benford & Snow 2000, p.614). Although not exclusively a conscious phenomenon, a rich literature from the study of social movements has highlighted the ways in which framing can be used as a tool to affect change. In this sense, framing can be understood as 'the *conscious strategic* efforts by groups of people to fashion shared understandings of the world and of themselves that legitimate and motivate collective action' (Snow, in McAdam, McCarthy and Zald, 1996:6 Emphasis added).

Although there are several different quantitative and qualitative methods applicable to framing analysis, this study uses Q method (see Box 1), to create a typology of frames in a systematic way so as to render these shared subjective constructions of the world observable (c.f. Dayton 2000). While various framing analyses have explored discursive elements in isolation (e.g. metaphors), in its application of Q method, this work aims to use an operant approach to allow participants autonomy to bring these framing elements together to constitute frames.

Data collection

The 'Q sort' is the basic unit of data in a Q study, and consists of a selection of subjective statements about the topic of interest, rank-ordered by a participant according to a particular instruction (for example according to those that are most-to-least like the participant's point of view). To select the statements that are to be sorted, the researcher first gathers as comprehensive as possible a selection of statements to reflect the diversity of opinions about the subject. This selection of statements is known as the 'concourse', and represents an attempt to capture the 'volume of discussion' on a given topic (Brown 1986, p.58). In this case, subjective statements about the topic of geoengineering were sought from a diverse range of sources, including academic papers, government policy documents, NGO reports, scientific and popular news media sources, television and radio interviews, blog posts and comments on online news sites. It is common practice within Q studies to include some statements that are 'deliberately ambiguous' (Dryzek & Berejikian 1993) or contain 'excess meaning' (Brown 1970). Because the statements do not just have one objective meaning set by the researcher, but are intended to act as stimuli to reveal the internal frames of reference of the participants, this ambiguity is not problematic as it would be in, for example a questionnaire design.

Box 1. Q method overview

Q is a 'quali-quantitative' method that can be used to examine the subjectivity inherent in any given topic around which there is social contestation, and as such, lends itself particularly well to the study of frames (c.f. Dayton 2000). Q has disciplinary roots in psychology (Stephenson 1935), but is now commonly applied across a range of disciplines including political sciences (Brown 1980; Dryzek & Berejikian 1993), geography (Eden et al. 2005); ecological economics (Swedeen 2006) and environmental policy analysis (Webler et al. 2009; Addams & Proops 2000). Q is an intensive 'small n' method in which a number of purposively selected participants (usually between 20 – 50) are asked to rank order a number of statements about a given topic. Outcomes are then statistically analysed using factor analysis to look for patterns in ways of thinking and talking about the topic (i.e. frames). Interview data and comments from the participants are used to aid interpretation of these patterns, and potentially to gain an insight into the more or less active processes of framing that different actors undertake. Although it has quantitative features, the method has a large qualitative component, and as with any other methodology, must be 'employed reflexively and creatively, with full awareness of its interpretative dimensions and not as a number-crunching exercise' (Eden, Donaldson, & Walker, 2005, p. 421). Q methodology does not impose categories of discourse onto the data, a priori, or position participants with respect to some pre-defined framework. Rather it asks its participants to decide what is or is not meaningful and relevant to their opinion by the process of sorting of statements. It has been argued that the method's potential to reveal discourses that might otherwise be obscured, might facilitate processes of 'opening up' policy to reflexive appraisal (Stirling 2007; Ockwell 2008), and proponents of the method have claimed that by allowing the researcher to 'surrender the monopoly of control in their relationship with the researched' Q method

can contribute to a more democratic research design and implementation (Robbins & Krueger 2000, p.636).

The concourse in this study consisted of 322 statements, after which point the research team decided that the addition of further statements did not add to the diversity of opinions present, and that 'saturation point' (Eden et al. 2005) had been reached. To narrow down the concourse to the sample of statements to be presented to participants, a structured approach was adopted whereby statements were categorised into a number of themes that were observed in the concourse as a whole. These were: 1) context (the nature of 'the problem'); 2) definitions and characteristics of geoengineering; 3) appraisals of geoengineering; 4) the relationship between science/research and deployment; and 5) governance concerns. Approximately equal numbers of statements from each category were sought, with the aim that each would capture a particular dimension of the issue around which opinion might be divided. The choice of the number of statements to be included in the final Q sample must balance the need to incorporate as great a diversity of statements as possible, against the need not to overly tax the abilities and patience of the participants. In line with a rule of thumb that suggests a Q sample size of between 20 – 60 statements (Webler et al. 2009, p.15), the final sample consisted of 48 statements. A pilot was carried out with 7 project members and colleagues in order to test the clarity of the statements, the comprehensiveness of the themes and topics covered by the statement sample, and the ease with which it was possible to sort them. Following the pilot a number of statements were removed because they were felt to be confusing or to duplicate existing themes in the sample, others were paraphrased for greater clarity, and a number of additional statements were added to cover themes that were felt by pilot participants to be missing. The final set of 48 statements is listed in Table 1.

Participants and the Q sort

The aim of this study was to uncover the different framings of the term geoengineering, hence the approach to participant selection was to focus on people who are or have been involved in debates and discussions around geoengineering, or those (self- selected) who would consider themselves to 'have an opinion' on geoengineering. The aim was not to try to elicit the views of some imagined wider 'public' as such, and no claim can be made that the sample group was in any sense representative of a larger population, but this is not the aim of a Q study (See Box 2). Rather, participants were selected on the basis that it was felt that they had the potential to reveal something interesting about the way in which debates around geoengineering are structured and the existing frames and framing strategies that are being employed. Based on an initial review of the academic and non-academic literature on the topic, a list of participants was drawn up to encompass a range of people involved in making

statements about geoengineering, and attempts were made to incorporate as diverse as possible a group of people (from different disciplinary backgrounds, sectors, nationalities and genders). This was complemented by a snowballing approach whereby participants were asked to identify other possible recruits with opinions that might differ from their own. Additionally an invitation to participate was circulated to the geoengineering Google list (an online forum for discussion on geoengineering [2]), Geoengineering Net Forum (a Japanese discussion forum[3]) and the African Technology Policy Studies Network[4]. Given that the interest of the study was in revealing framings, rather than making any attempt to test the validity of viewpoints, the sole criterion for participation for those people responding to the general invitation was that participants considered themselves to 'have an opinion' about geoengineering. This criterion was applied based on the rationale that in order to have formulated an opinion on geoengineering an individual would need to have engaged with debates and discussions around the topic in some way, and their opinion would thus be as representative as anyone else's of the types of framings of the issue that are emerging.

Box 2. The notion of 'sample size' and generalizability of findings in a Q study

Within traditional quantitative ('R') methods, the term 'sample size' refers to the number of participants, and is ideally as large as possible in order to be statistically representative of the larger population from which participants have been sampled, and thus to make it possible for inferences to be made about that population on the basis of the results of measurements of the sample. In Q methodology, the concept of sample size is more applicable to the concourse of statements, and the notion of representation is relevant in as far as the statements in the concourse should be representative of the total range of statements being made about the topic. Thus participants for a Q study are not randomly sampled from a population, but are deliberately chosen for their relevance to the topic in question (Brown 1980). The most important principle of participant selection is diversity of opinion, so that ideally if a particular discourse exists, even if is very marginal, the process would hope to reveal it. It is also important that the participants are familiar with the topic and have 'well-formed opinions' (Webler et al., 2009 p. 9).

Given that the aim of a Q study is to search for distinct subjective viewpoints or framings of a given issue, and no claim is made about the proportions of the views uncovered in a wider population, the same need for large sample sizes does not apply in a Q study. Rather as Dryzek & Berejikian point out 'our units of analysis, when it comes to generalization, are not individuals but discourses' (Dryzek & Berejikian 1993). Thus although no claim can be made that the subjects who carried out the Q test are

[2] https://groups.google.com/forum/?fromgroups#!forum/geoengineering
[3] http://geoeng.brs.nihon-u.ac.jp/
[4] http://www.atpsnet.org/

statistically representative of some larger population this is not the aim of a Q study. Instead in so far as the concourse is 'representative' of the breadth of opinion on the topic each factor described should 'prove a genuine representation of that discourse as it exists within a larger population' (Dryzek and Berejikian, 1993 p. 52). And thus although it cannot be asserted that the factors uncovered by this study are the only viewpoints that exist on the topic, the discovery of factors other than those described (for example through the participation of an additional individual with a unique point of view) should 'in no way influence description' of the existing factors (Brown, 1980 p. 67).

Furthermore, within a Q study, individual cases are not treated as anomalies, or insignificant, but can provide valuable insights to the topic in question. As Brown explains, given that 'the interest of Q methodology is in the nature of the segments [discourses] and the extent to which they are similar or dissimilar, the issue of large numbers, so fundamental to most social research, is rendered relatively unimportant. In principle as well as practice, single cases can be the focus of significant research' (Brown, 1993 p. 93).

Participants were asked to sort the statements into a grid along a scale from +4 (most like their point of view) to -4 (least like their point of view). As is common in Q studies, the grid had a pyramidal or 'quasi-normal' shape, which limited the number of statements that could be placed in each category (See Figure 1). Although the imposition of this distribution shape is not necessary for the technique to work (Brown 1971; Burt 1972; Barry & Proops 1999), it is considered good practice as it encourages the participants to consider the relative placement of the statements more carefully and hence to reveal their preferences more thoroughly (Webler et al. 2009). In the majority of cases participants carried out a Q sort during a face-to-face interview with the researcher, and (with participant consent) comments made at the time of the Q sort were recorded to aid interpretation. Interviews lasted between 25 minutes up to 1.5 hours, averaging approximately 1 hour.

In addition, to maximise the diversity of the participant group and facilitate participation from international participants, there was an option for participants to take part via an online interface using Q-Assessor (http://q-assessor.com), a tool specifically designed for online Q studies. The online study can be accessed (and carried out) by visiting http://q-assessor.com/studies/753/responses/new. The use of a combination of face-to-face Q sorts and online sorts has precedents in the literature on Q method (e.g. Gruber 2011) and is supported by empirical work which has shown there to be no apparent difference in the reliability or validity of face-to-face sorts and those carried out remotely by mail (Van Tubergen & Olins 1979); between paper sorts and online sorts in general (Hogan

2010); and between paper sorts and the specific online sorting program we applied in this study, Q-Assessor (Reber et al. 2000).[5]

Thirty-five people, including 5 people involved with the Geoengineering Governance Project in various ways, carried out a Q sort. The inclusion of researchers' own Q sorts is considered good practice in scholarship on Q methodology (Robbins & Krueger 2000; Swedeen 2006). Given that there is no such thing as a truly 'frame neutral position' (Schön & Rein 1995, p.38) from which to examine framings, in this study it was decided that to enhance both the reflexivity and transparency of the Climate Geoengineering Governance Project, it would be desirable both for the lead researcher and others less directly involved in this component of the project to reflect upon and reveal their own positionality within these debates. With participant permission, the list of participants and their institutional affiliations (where applicable) are listed in Appendix I. Twenty-one individuals carried out face-to-face interviews, while thirteen people carried out the Q sort online[6]. Participants who carried out a web-based sort are distinguished in the results table by the letter (W), while individuals associated with the Climate Geoengineering Governance project, including the author, are distinguished by the letters CGG.

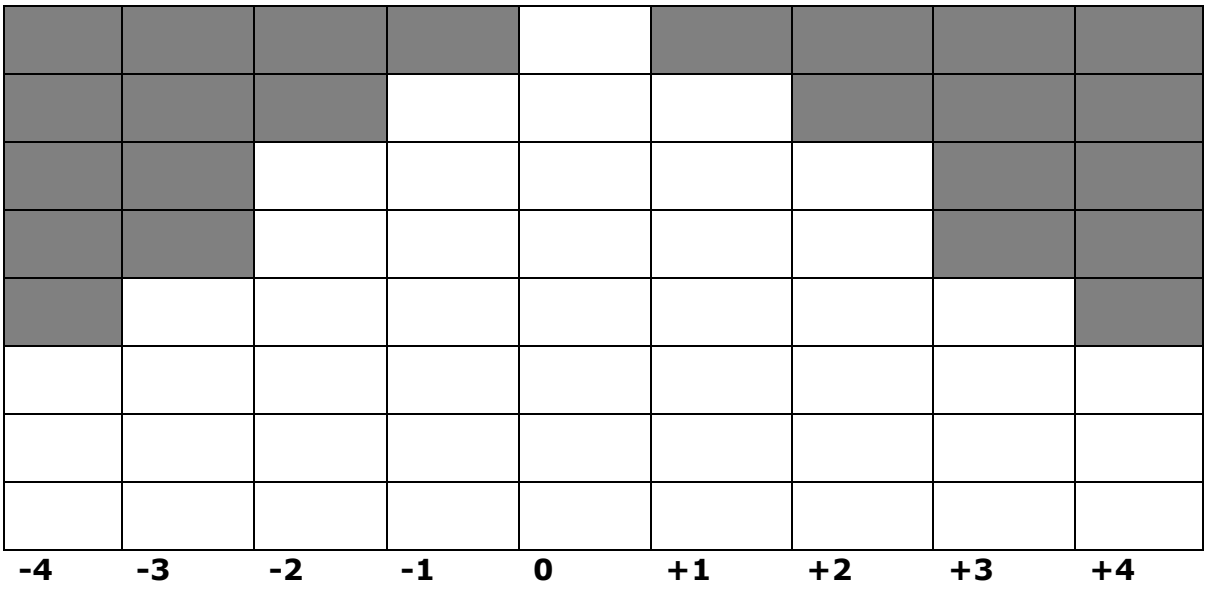

Figure 1. The distribution shape onto which participants were asked to sort the statements in the Q sample.

[5] Although more qualitative data can be collected from face-to-face interviews as compared to online sorts (and hence a possible bias emerges in the fact that these sorts might be more fully interpreted than the online sort patterns), the benefit to the overall study of being able to incorporate a greater diversity of participants was felt to outweigh this concern.

[6] The author's own Q sort brought the total number of sorts to 35.

Analysis

The 35 sorts were analysed with the freely available software PQMethod (Schmolck 2002). Each sort was correlated with every other sort, and a 35 by 35 correlation matrix was generated. Principal components analysis was then used to identify clusters of similarly performed Q sorts, and the resulting factors were rotated using a varimax rotation that aimed to find the simplest structure in the data and to explain the greatest amount of variance.[7] It is important to bear in mind that there is not just one objectively 'correct' or 'mathematically superior' solution regarding the number of factors that emerge from a Q study (Watts & Stenner 2005, p.80). Rather, although the data itself is 'fixed' in the sense that the correlation scores between individual Q sorts do not change, there could be many vantage points from which to view and describe the similarities and differences between views, that are largely dependent on what one is interested in (for example, whether one is interested particularly in revealing minority views, or examining more dominant discourses). In this study a solution was sought that maximised the simplicity, clarity, distinctness and stability of the emerging framings (Webler et al. 2009, p.31), and ensured that at least 2 individual Q sorts correlated uniquely with each factor (cf. Brown, 1980 p. 293).

Based on these criteria, a three-factor solution was selected as optimal. However, scrutiny of the results revealed that one of the factors was 'bipolar': certain individuals' sorts were highly positively correlated with this factor, while others were highly negatively correlated, indicating the presence of two groups of people who sorted the statements in more or less opposite ways. In line with standard practice in Q studies (Brown 1980), the bipolar factor was split into two separate factors (highly negatively correlated with one another) resulting in a final solution consisting of the four factors that will be described below.

Correlations between an individual's Q sort and a given factor were deemed as being statistically significant at the $p<0.01$ level, if they exceeded a factor loading of +/-0.38, based on the equation: $2.58 \times (1/\sqrt{n})$, where n = the number of statements in the Q sample: $2.58(1/\sqrt{48}) = 0.3723$ (Brown 1980). Sorts that were significantly correlated with a factor (i.e. those that load at +/-0.38 for that factor) were considered representative of that view, and the weighted average of those sorts were used to calculate an idealised sorting pattern for that factor along the original response scale (-4 to +4). These idealised sorting patterns are listed in Table 1. The degree to which each

[7] It is also possible to extract factors using the centroid method, and to rotate factors 'by hand' in order to explore the data based on particular theoretical hypotheses about how particular clusters relate or how particular individual's sorts fit into the overall picture, and some researchers argue that this is the preferable approach (Brown, 1980). In this instance both procedures were carried out and the results compared. While not substantially different, principal components analysis and varimax produced the clearest and most stable and interpretable result.

participant's sort correlated with each factor is described is given in Table 2. The degree of correlation between factors is given in Table 3. Narrative descriptions of each factor were drafted by examining these idealised sorting patterns and analysing the interview comments made by those people's whose sorts were significantly correlated with that factor. Draft descriptions of these factor narratives were sent to all participants, who were asked to comment on whether they felt that their views had been appropriately represented. These comments were used to test the validity of the views described.

Table of statements sorted by participants, and the idealised sorting pattern (from -4 to +4) for each factor

Statement:	Idealised sort pattern			
	1	**2**	**3**	**4**
1. Geoengineering is about fruitlessly trying to solve problems with the same mind-set that created them: attempting to control nature.	-3	-4	2	-3
2. Geoengineering can only ever be fundamentally undemocratic.	-2	-1	1	-4
3. The risks of not doing geoengineering research outweigh the risks of doing it.	3	2	-2	1
4. Hasty pursuit of international regulation of geoengineering risks lock-in to commitments that might soon be regretted, such as a total ban on research or testing, or burdensome vetting of even innocuous research projects.	1	3	-2	0
5. Calls for more science on geoengineering don't really make sense: full trials are unethical and small scale experiments are pointless (since any impacts are drowned in the noise of global weather).	-4	-3	2	-3
6. We might once have trusted nature to look after the environmental regulation, but not any more: like it or not, we are the planetary maintenance engineers.	1	3	-2	-1
7. Deliberate geoengineering of the climate has been happening for decades; the current suggestion that it's all about dealing with climate change is just a front intended to legitimize on going activities that have other motivations.	-4	-2	0	-1
8. One of the central motivations for the growing interest in geoengineering research is the potential for strategic military applications of these technologies.	-4	-2	1	1
9. The belief that technological solutions can be found to social problems, and to problems arising in earlier technological development, is a dangerous illusion which fails to address political and social drivers and implications.	-1	-1	3	-1
10. Geoengineering is a bit like chemotherapy: the decision to undertake it would be difficult, but it could turn out to be the least bad option we are going to have.	2	1	-3	-2
11. Carbon emissions will never be reduced to zero because this would require a complete change in the way humans are.	0	2	0	-4
12. At the very least, we need to do more research in order to learn what approaches to avoid even if we become desperate.	4	2	0	3
13. It is inappropriate to make geoengineering research decisions subject to 'upstream engagement' or public control.	-2	0	-4	-2
14. Geoengineering is the most revolutionary and potentially valuable new idea in climate policy today.	-3	2	-1	-3
15. Geoengineering is potentially the key to unlock the mitigation puzzle: a way of controlling climate risks during the many decades that it will take to transform the global energy system.	0	1	-3	1
16. The idea of actually deploying a geoengineering system would be very controversial, but the narrower question of a research program should not be.	3	-1	-1	-1
17. The climate system is too complex and chaotic to judge cause and effect of various geoengineering ideas, even as we try them out.	-2	-2	1	4
18. After realizing that our actions en masse affect the climate, anything we do to address it (including nothing), is geo-engineering.	-3	1	-2	3
19. The technical community has a responsibility to explore back-up strategies for dealing with an unexpected climate emergency.	1	2	-1	1
20. We use technology to clean up land and water, so why not clean up the	1	1	0	1

contaminated sky?				
21. Attempts by us to regulate the Earth's climate and chemistry would condemn humanity to a Kafkaesque fate from which there may be no escape.	-1	-4	2	-2
22. The laudable goal of combating climate change has no business in the definition of geoengineering, as it suggests that technologies do, in fact, combat climate change giving the whole suite of planet-altering technologies a veneer of respectability they have not earned.	0	-1	1	-1
23. Some geoengineering technologies might be able to provide win-win solutions, allowing economic growth and climate change mitigation to proceed hand in hand.	0	2	0	2
24. More than a set of technologies, geoengineering is a political strategy.	-1	0	3	2
25. Until there has been a full debate on the course all countries wish to go, it is common sense to institute a moratorium on all geoengineering activities outside the laboratory.	-2	-4	4	2
26. Much current policy discussion of 'geoengineering governance' makes no reference to the possibility that the world could decide not to go down this path, and is thus little more than a marketing exercise.	-2	-1	1	0
27. Commercial involvement in geoengineering, including competition, may be positive in that it mobilizes innovation and capital investment, which could lead to the development of more effective and less costly technologies at a faster rate than in the public sector.	1	1	-2	1
28. 'Encapsulated' geoengineering technologies are ethically preferable to non-encapsulated technologies.	2	-1	0	1
29. In a geoengineered world, rather than finding deep meaning in our natural surroundings, humanity might start to view them as a constant potential threat.	-1	-3	0	-2
30. Complex control systems never work perfectly, humans can make mistakes in design, manufacturing, and operation (think of Chernobyl, the Exxon Valdez, airplane crashes etc); given this fallibility, it is unwise to stake so much on a more complicated arrangement than anything attempted before.	0	-2	4	3
31. There are such things as morally bad research projects.	3	0	2	3
32. We don't have the luxury of waiting around for a change in attitude that is never going to happen, or until it is far too late for action.	1	4	-2	2
33. Government support for geoengineering research is important, because good policy decisions depend on good science.	3	2	0	2
34. A ban on geoengineering would be unenforceable and counter-productive as those carrying out tests would do so in secrecy.	0	1	-3	-2
35. Geoengineering technologies will not "solve" the climate change "problem"; rather, they will redesign major Earth systems - including not just natural but human and built systems - powerfully, unpredictably and potentially irreversibly.	0	-3	3	0
36. Substantial investment in geoengineering research will encourage political inertia on mitigation and adaptation, and also facilitate the actual deployment of geoengineering "solutions".	-1	-2	2	-1
37. In a nutshell: someone, somewhere is going to do geoengineering research, so it might as well be someone responsible.	2	0	-1	-2
38. Given that geoengineering experiments are already underway - uncontrolled, unmonitored, illegal - then it is time for the world to have a serious conversation about geoengineering.	2	0	2	0
39. Even if we stopped emitting any greenhouse gases right now, we'd still have	4	0	-1	0

locked in at least 1.5 degrees of warming, probably more, and there's no sign that we're going to stop emitting any time soon. So some kinds of geoengineering might be a necessity, not as a solution, but as a postscript to a solution.				
40. Although there is a lot of variety in the geoengineering approaches being proposed, at the end of the day they are technological fixes - and so flawed.	-3	-3	1	-4
41. It is likely that *some* new technologies will be needed to move to lower-polluting energy systems and to adapt to likely climatic changes; but the types of technologies pursued, the interests they favour and the future societal vision they serve (or suppress) ought to be the subject of public deliberation and ultimately public control.	2	-1	4	4
42. The governance challenges of controlling the global climate through geoengineering are more difficult to overcome than those of transforming the global energy system.	1	-2	1	0
43. Since we know that accumulating carbon dioxide in the atmosphere is a problem requiring action, then we need to focus our energies on finding ways of taking it out and storing it somewhere safe and permanent, the same way we do with problems like nuclear waste and arsenic in water supplies.	0	3	-1	4
44. The anti-geoengineering people are ideologically motivated and rely on doom and gloom stories about the environment; the last thing they want to see is that some of these techniques might work.	-1	0	-4	-1
45. All of the technologies needed to meet global 2020 emissions reductions exist today.	4	0	3	-3
46. It's not a question of if but *when* humanity will be compelled to use geoengineering.	-1	4	-4	0
47. There is an important difference between geoengineering field experiments that do not cause damage to the environment, and those that specifically aim to perturb natural systems; so a blanket ban on field testing doesn't make sense.	2	1	-1	2
48. Right now, the Arctic (and hence the Earth) is in a state of dire emergency, and only immediate drastic action, including some forms of geoengineering, can save us from catastrophe.	-2	4	-3	0

Table 2. Degree to which each participant's sort correlated with each factor

Participants (by professional sector)	Degree of correlation of Q sorts with each factor			
	1	2	3	4
Participants whose sorts correlate with just one factor:				
Media	**0.7146***	0.2620	-0.2620	0.3663
Academia (physical/natural sciences)	**0.5894***	0.2479	-0.2479	0.1008
Academia (physical/natural sciences)	**0.6133***	0.1971	-0.1971	0.1116
Government	**0.8248***	-0.0039	0.0039	0.0494
Academia (physical/natural sciences)	**0.6957***	0.0514	-0.0514	0.2540
Academia (physical/natural sciences)	**0.5064***	0.3414	-0.3414	0.0585
NGO	**0.5218***	-0.2054	0.2054	0.3222
Academia (physical/natural sciences)^{W}	**0.5637***	-0.2639	0.2639	0.0650
Academia (physical/natural sciences)	**0.6423***	-0.0186	0.0186	0.3463
Industry	**0.6968***	0.2824	-0.2824	0.2885
NGO	0.3744	**0.6110***	-0.6110	0.2209
NGO	0.1652	**0.7993***	-0.7993	0.2589
NGO	-0.1203	-0.7913	**0.7913***	0.1451
Academia (social sciences/humanities)^{W}	-0.3013	-0.7216	**0.7216***	0.0222
Media^{W}	-0.1471	-0.7851	**0.7851***	-0.0880
Academia (social sciences/humanities)$^{(CGG)}$	0.2630	-0.6437	**0.6437***	0.2930
Academia (social sciences/humanities)^{W}	-0.0386	-0.8237	**0.8237***	-0.0222
Academia (physical/natural sciences)	0.3661	-0.2500	0.2500	**0.6441***
Industry	0.1517	0.0618	-0.0618	**0.5440***
Industry^{W}	0.3012	-0.1675	0.1675	**0.5893***
Academia (social sciences/humanities)	-0.2322	0.1116	-0.1116	**0.7681***
Participants whose sorts correlated with more than one factor:				
Government	**0.6669***	**0.4148***	-0.4148	-0.0534
NGO	**0.6418***	0.0730	-0.0730	**0.4445***
Industry^{W}	**0.405***	**0.4904***	-0.4904	**0.4047***
Academia (physical/natural sciences)^{W}	**0.4325***	-0.0165	0.0165	**0.4227***
Industry^{W}	**0.4206***	**0.5229***	-0.5229	**0.4998***
Academia (social sciences/humanities)^{W}	**0.4087***	-0.4449	**0.4449***	0.1662
Academia (physical/natural sciences)^{W}	**0.5006***	-0.3921	**0.3921***	-0.0582
Academia (physical/natural sciences)	**0.5248***	0.2192	-0.2192	**0.5806***
Industry	**0.5671***	**0.5335***	-0.5335	0.0511
Academia (social sciences/humanities)$^{W(CGG)}$	**0.5572***	0.0330	-0.0330	**0.5167***
Industry^{W}	**0.6124***	**0.4552***	-0.4552	0.3127
Academia (physical/natural sciences)$^{(CGG)}$	**0.519***	**0.4099***	-0.4099	0.3618
Academia (social sciences/humanities)$^{(CGG)}$	0.0775	-0.5757	**0.5757***	**0.5035***
Academia (social sciences/humanities)$^{W(CGG)}$	0.1935	-0.6088	**0.6088***	**0.5097***

***** Indicates that a sort correlates significantly with the factor at the $p < 0.01$ level; **(^{W})** indicates that an individual carried out a web based Q sort using Q assessor; **(^{CGG})** indicates that an individual is associated with the Climate Geoengineering Governance research project, including the author.

Table 3. Correlations between factors.

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1	0.4015	-0.2080	0.3588
Factor 2		1	-0.7225	0.2007
Factor 3			1	0.0726
Factor 4				1

Results

Narrative descriptions of the four factors that emerged from analysis are given below. The factors were assigned names drawn from statements that were ranked particularly highly for that factor, and act as an abbreviated story line, capturing some essence of the larger narrative. The numbers in square brackets within the text refer to the statement upon which the interpretation is based (see Table 1). It will be noted (in Table 2) that a number of individuals' Q sorts correlated with more than one factor which suggests that 'there is not necessarily radical discontinuity across discourses' (Dryzek & Berejikian 1993), and that many individuals have access to, and may move between discourses or framings (c.f. Collins & Yearley 1992). The relatively high number of these individuals might also be illustrative of the fundamentally ambiguous nature of the term geoengineering, or perhaps suggestive of the fact that around and between the more stable framings described below, the discursive landscape is characterised by a high degree of ambivalence as people struggle to formulate opinions incorporating contradictory normative positions. Although the framings will be described below as discrete in order to facilitate an exploration of some of the different tensions within and between them, it should be remembered that this is not actually the case

Factor 1: "At the very least we need more research"

Ten participants' sorts were correlated significantly with this factor, including six individuals from academic (natural/physical science) backgrounds, one journalist, one government employee, one non-governmental organisation professional, and an individual from an industrial background. This framing has been summarised as follows:

Action on climate change is clearly urgent [39], but arguments that frame the need for geoengineering in terms of an emergency are unhelpful and counterproductive [48]. Geoengineering is certainly not the most revolutionary new idea in climate policy [14], however we shouldn't rule any options out, and at the very least we need more research in this area to understand what approaches won't work and should be avoided at all costs [12]. Research is the only way to determine the potential impacts of different technologies, and we have now achieved the level of scientific sophistication to make research in this

area worthwhile [5, 17]. Research is clearly distinct from deployment, and if carried out in a responsible manner, should not be overly controversial [16]. Indeed, if responsible parties don't carry out research, it will be done by less responsible parties [37]. Furthermore, the technical community has a responsibility to explore back-up strategies for dealing with possible future climate emergences [19]. Now is the time for a serious societal conversation about if and how we want to develop these different technologies [38], and public involvement in choices about directions of research and development in this area are crucial [13, 41]. Regulation of research is important, but should be undertaken carefully, as there is a risk that hastily developed regulation might be counter-productive and stifle innovation and scientific freedom [4]. Given the variety of different research activities that might take place a moratorium on all activities outside the laboratory doesn't make sense [25, 47]. Although the deployment of geoengineering is by no means inevitable [46], and we already have all the technology we need to reduce emissions [45], some kinds of geoengineering will probably be a necessary part of any solution [39]. Geoengineering technologies that are likely to be more ethically preferable are 'encapsulated technologies' such as air capture, rather than non-encapsulated techniques such as stratospheric aerosols or iron fertilization [28]. Commercial involvement in geoengineering might be helpful [27], but we should probably be wary of claims of technologies to provide win-win solutions allowing economic growth and mitigation to proceed hand in hand [23].

Factor 2: "We are the planetary maintenance engineers"

Two participants' sorts were correlated significantly with this factor, both of whom are associated with non-governmental organisations. The framing has been summarised as follows:

We are currently in an unprecedented planetary emergency brought about by climate change [4], immediate action is urgent [32], and it is likely to be only a question of time before humanity is compelled to use geoengineering [46]. Geoengineering is an important part of the solution to climate change [35, 40], hence, research on geoengineering is both crucial and worthwhile [5, 17], and should be supported by governments as the best basis for sound policy making [33]. Humans have demonstrated their ability to build functioning complex control systems [30], and now need to apply that knowledge to the task of planetary maintenance engineering that (like it or not) now falls upon us [6]. Given the dire state of the climate, neither research nor deployment of geoengineering should be overly controversial [16]. Although there might be some risk associated with research, not carrying out research given what we know about climate change would be riskier [3]. Only through research can we learn what technologies might be helpful, and conversely which shouldn't be deployed [12]. Investment in geoengineering research isn't likely to have a significantly negative impact on policies towards mitigation and adaptation, especially when one considers the dire state that mitigation policies are in

already [36], and while the governance of geoengineering brings particular challenges, these are likely to be less difficult to overcome than the challenges of transforming the global energy system [42], which so far appears to have failed. Indeed geoengineering has the potential to revolutionise climate policy [14], opening-up possibilities for economic growth and climate change mitigation to proceed hand in hand [23]. We should not be too hasty in pursuing regulation, which might be stifling to innovation and research [4]. A ban on geoengineering would just be counterproductive [25], likely resulting in research being carried out in secrecy or by less responsible parties [34, 47]. Those carrying out research are motivated by a desire to find solutions to the climate change problem, and for developing 'back-up' strategies for dealing with a possible future climate emergency [19], rather than any other motivation [8, 7]. Given the urgency of the problem, commercial involvement in geoengineering might be positive in terms of mobilizing innovation and capital investment, possibly increasing the speed with which these technologies could be developed [27].

Factor 3: "Geoengineering is a political strategy"

Five participants' sorts were significantly correlated with this factor, including 3 individuals from academic (social science/ humanities) backgrounds, one journalist and one individual associated with a non-governmental organisation. This framing has been summarised as follows:

Geoengineering won't solve climate change, but is likely to cause unpredictable and irreversible damage to the planet [35]. Attempts to control the climate through geoengineering are neither feasible [30], nor inevitable [46], and would likely lead humanity to a dystopian future in which we would find ourselves trapped by the consequences of our hubristic actions [21]. Geoengineering proposals stem from the same mind set of attempting to control nature that got us into the environmental mess we are in today [1], and are built on the dangerous illusion that complex social problems can be solved with technology [9]. The idea that all of the proposed technologies can be defined as geoengineering because their stated intent is to deal with climate change, is misleading [22]. More than as a set of technologies defined by a stated shared intent, geoengineering can be thought of as a political strategy [24] that serves the interests of the status quo. The commercial interest in some of these technologies only serves to highlight this, and if we were really serious that geoengineering was about 'saving the planet' we wouldn't leave such a task to business [27]. We have all the technologies we need to mitigate carbon emissions effectively; it's just a question of using them [45]. More research into new technologies isn't the most crucial thing [12], indeed, the risks of doing research (including the risk of strategic military applications of these technologies [8]) may well outweigh the benefits [3]. It isn't possible to separate out research from deployment in any straightforward way, and both should be considered controversial [16]: carrying out research, especially field trials, is the first step toward deployment, and drawing distinctions between different types

of field test only serves to obscure this fact [47]. Since full-scale trials are unethical and small-scale trials can't produce useful data in the noise of global weather [5], it is common sense to institute a moratorium on all testing activities outside the laboratory [25]. The argument that 'someone somewhere will do it, so it might as well be us' [37] is not acceptable, nor are arguments stemming from claims of present day [48] or hypothetical future emergencies [12]. The governance challenges of controlling the global climate through geoengineering would likely be more complex and difficult to overcome than those of transforming the global energy system [42], and given the undemocratic and risky nature of proposals for geoengineering, we probably shouldn't be going down this path [21]. Publics need to be engaged meaningfully in decisions about research [13], and ultimately have control over which (if any) of these technologies are to be pursued [41]. However, much talk of governance seems to see deployment as inevitable, and is hence a purely instrumental exercise for smoothing this process, rather than allowing genuine dissent to emerge [26].

Factor 4: "Let's focus on carbon"

Four participants' sorts were significantly correlated with this factor, including two individuals from industrial backgrounds, and two individuals from academic backgrounds (one social scientist, one natural scientist). The framing has been summarised as follows:

Action on climate change is urgent [32], and is likely to require the development and deployment of new technologies [45], including some that might be labelled as geoengineering [39]. However, the definition of geoengineering is slippery and after realising that our actions en masse affect the climate, anything we do to address it (including nothing) might be considered geoengineering [18]. Although ambiguous, the concept of geoengineering might be useful as a political strategy to help open up the solution space available to us for dealing with climate change [24]. There is nothing wrong with a technological fix per se [40, 20], but it's important to remember that technology alone will not 'solve' the climate change problem [35]. It is important to ensure that the direction of development of these technologies is the subject of public deliberation and control [41], so that, appropriately managed, Geoengineering does not have to be fundamentally undemocratic [2]. We clearly need research into new technologies, if only to be able to rule out those that shouldn't be deployed [12], but some research is more morally acceptable [31] than others, and the argument that 'someone will do it so it might as well be someone responsible' (i.e. us) is problematic [37]. Research cannot be neatly separated from deployment, and thus it is difficult to defend the idea that only deployment should be controversial [16]. For this reason publics should be engaged 'upstream' in the direction of research in this area [13]. The inherent complexities of the climate system limit the human ability to predict and judge cause and effects of interventions [17]. This complexity, coupled with human

fallibility, means that attempts to control the climate system are likely to fail [30]. Hence we should focus our energies on removing carbon dioxide from the atmosphere [43] (an endeavour in which commercial involvement might be helpful [27]), so that with the right technological and social changes, a carbon neutral future for humanity can be achieved [11], and mitigation and continuing economic activity can take place [23].

Discussion

No claim is made that the four framings of geoengineering that have been described above, constitute any kind of comprehensive, authoritative or final set of framings. As in any study of discourse (whether acknowledged or not), these might rather be thought of as stylised representations that will hopefully be of heuristic utility in offering 'tools to think with' in processes of further enquiry (c.f. Brand & J. Fischer 2012). This discussion will draw out some of the tensions between and within the different framings, starting with an examination of the fluidity and ambiguity of the term itself and the definitions of geoengineering given by participants, before examining how concepts of control, research, novelty and interests all feature within and constitute the different framings of geoengineering.

Given the existence of campaigns both for[8] and against[9] geoengineering in general, one might expect to find opinion around geoengineering highly polarised. The emergence of a bipolar factor (split into factors 2 and 3), indicating highly opposed views, is therefore perhaps unsurprising. The prominence of this axis also confirms the general salience for this purpose of an aggregated concept of 'geoengineering'. However, the existence of a further two factors clearly indicates that the picture is not as simple as a description of a straightforward 'pro' /'anti' axis might suggest. With regard to the coherence or ambiguity of the term geoengineering, it appears that (although the most different in terms of their framing of geoengineering) individuals loading on factor 2 (broadly in favour of geoengineering), and factor 3 (decidedly against geoengineering), actually appeared to find it less problematic making statements about geoengineering as a non-differentiated category, than those loading on factors 1 and 4. Thus for example, within the factor-3 framing, a total ban on all geoengineering activities outside the laboratory is a necessary and coherent thing to call for [25]. Likewise within the factor-2 framing, geoengineering (in general) is one of the most revolutionary new ideas in climate policy [14]. Interview data collected at the time of the Q sorts can be instructive in understanding this. Thus a participant whose sort correlated with factor 2 explained why he considered the term geoengineering to be useful:

> 'The term has proven to be very useful because of the discussions it catalyses. I view the real utility of geoengineering not really as being the technological interventions but as being so extreme as a concept that it actually provokes imagination and the ability to open up discussions that are otherwise mired in more detailed political positions…it opens up new opportunities for reframing how we deal with climate…'

On the other hand the following quote from a participant whose sort correlated with factor 3 illustrates why he feels it is meaningful to object to geoengineering

[8] E.g. AMEG (the Arctic Methane Emergency Group) www.amegme
[9] E.g. The HOME (Hand's Off Mother Earth) campaign http://www.handsoffmotherearth.org/

is possible, and disaggregating the term is not considered to be of primary importance:

> 'I just think there's a broader thing afoot about trying to solve problems through technological solutions rather than the heavy lifting of social change and actually addressing the root causes and so forth, and geoengineering in some way I think is totemic for that… it's not just about a geoengineering solution, it kind of speaks to, we're going to have a technological solution for this, whether its carbon capture and storage or biofuels or air capture or nuclear power, whatever it is, we're going to craft a technological way round this, such that we don't have to significantly disrupt the economy…'

But while this participant appears to be able to object to geoengineering as illustrative of a broader (in his view) problematic attitude towards the application of technology to social and environmental problem solving, , participants loading on factor 1, appeared much less willing to take such a general or abstract stand. A fairly typical quote from a participant loading on factor 1 illustrates this:

> 'My reaction to the term is that it isn't particularly helpful because it describes different groups of approaches. So there's negative emissions, taking carbon out of the air, carbon dioxide removal I guess it's called in the academic world, which is a very different set of interventions than the solar radiation management stuff. So geoengineering is a catch-all term that creates challenges for us to then have a clear position on… and within those there's lots of different approaches which each have their pros and cons and different risk profile.

Another commented:

> 'I don't want to have a debate about the terminology too much, I think I want to have a debate more about what the technologies do to our climate and I don't think having huge arguments about what a term is or not really make much difference to that'.

Interestingly, although the factor-1 perspective appears to find the 'catch all' nature of the term presents a problem for the making of general statements about geoengineering, and prefers to focus attention on individual technologies, this view is very clear about what geoengineering is *not.* Hence it appears from the negative score awarded to statement 18, that the definition of geoengineering (while encompassing a broad range of technologies) does not include those activities the effects of which were inadvertent.

A different perspective still was offered by factor 4, whose agreement with statement 18, suggest a distinctive take on the issue of intent, and a broader understanding of what might constitute geoengineering. For example, one factor-4 participant defined the term to include interventions not generally

classed as technological, such as the implementation of a carbon tax (See definition 7 in Table 4 below). While subscribing to a very broad definition of the term itself (to the extent that it might be difficult to differentiate from other categories of effort such as mitigation), factor-4 participants were also conscious of the possible utility of the term itself as offering something distinctive on the discursive level at least. Hence one participant argued against the so-called 'moral hazard' argument against geoengineering research [36], by referred to the fact that arguments against geoengineering such as this act to prematurely close down 'the solution space, the option space that you want to keep open.'

Understanding 'the strategically and politically loaded negotiation of definition and meaning' (Walker & Shrove 2007, p.216) is crucial to understanding framing, and definitions themselves can be understood as key elements of wider frames. Table 4. lists a selection of definitions of geoengineering given by participants.[10]

Table 4. Selection of participants' definitions of geoengineering

	Definitions of geoengineering (factor number(s) with which participant's sort correlated).
1.	'Deliberate large scale interventions in the earth's natural systems' (1/4)
2.	'I suppose I've been influenced quite a bit by the Royal Society report and its very inclusive definition of geoengineering to include any deliberate attempt to change the climate, to fix the climate… Any deliberate attempt to fix the climate apart from cutting our actual emissions'. (1)
3.	'To me it means intentional technical interference with atmospherics in order to mitigate some or all of the impacts of anthropogenic climate change…my framing would always be to have something to do with the impacts of climate change …I guess I can't see why [weather modification for other purposes] wouldn't be included…but all the discussions I've had have been with the climate change community and it has been a climate change framed discussion'(1)
4.	'I guess the scientific definition would be: the modification of climate variables to offset rising greenhouse gas concentrations and associated rise in temperature'(1)
5.	'Large scale, intentional attempts to change the climate system and other large scale systems' (3)
6.	'All sorts of technological ways to combat climate change, so I'd be including removing green house gases, so particularly things like carbon scrubbing that takes out carbon dioxide and buries it underground, and also what they call solar radiation management, actually reflecting the sun. To me it's all those things' (2)
7.	'Geoengineering is the intentional intervention in the global planetary system to affect weather and climate… I am agnostic on what those interventions are, I don't differentiate geoengineering by methodology, so if you capture carbon from smokestacks in coal plants, or you implement a carbon tax, or you put particulates in the stratosphere, those are all examples of geoengineering…. (4)
8.	'What it conjures up to me really is talking about the global climate change, and thinking of technological solutions that can either dramatically speed up the rate of mitigation of

[10] Not all participants provided definitions (those carrying out online sorts for example were not asked to define geoengineering), and there was a degree of repetition among those that did, hence the table is not a comprehensive list, but offers a selection indicative of the diversity of definitions given.

climate change or do something different, that is prevent some of the worst effects of climate change' (1)

9. 'It's about humans taking interventions to try and control the climate system, which we've never deliberately done before even if we are now changing the climate system through our pollution, so it crosses a particular barrier…' (1/4)

10. 'I just stick to the Royal Society definition really: deliberate, large scale manipulation of planetary environment in order to counteract anthropogenic climate change' (3)

11. [Climate remediation] 'is trying to have available one or more, preferably a set of technologies such that if the planet gets into a really rather unfortunate situation with respect to the people living on it and the environment more generally you don't have to live with the situation for hundreds and hundreds of years even if you shut down greenhouse gas emissions' (1/2)

12. 'When I say geoengineering I mean something like solar radiation management. Geoengineering via carbon dioxide removal is a lot more blurred between geoengineering and mitigation, because is planting the Amazon rainforest and re-growing lots of trees mitigation? Or is it geoengineering because we're going to be locking up a lot of carbon in those trees? That is a very blurry line' (1)

An examination of the definitions reveals potentially significant 'grey areas' and ambiguities in the term. For example: is geoengineering defined as being solely about interventions in the climate system (e.g. 2, 3, 4), or could the definition also include any large-scale natural system (e.g. 1, 5)? Is geoengineering defined as being about purely 'technical' or 'technological' interventions (e.g. 3, 6), or could it also encompass economic or social changes (e.g. 7)? At what scale does an intervention become geoengineering? Is weather modification included (e.g. 7), or is it only about global change (e.g. 3, 8 10)? Is the attempt to counteract climate change fundamental to the definition of geoengineering (e.g. 3, 4, 6, 10), or could an intervention be defined as geoengineering if carried out with other intent (e.g. 1, 5)? Is it primarily about control (e.g. 9)? Should it actually be called something else, such as climate remediation (e.g. 11)? Or should the definition be narrowed down to just solar radiation management and exclude carbon dioxide removal (e.g. 12)?

While the term's ambiguity is therefore clear, it might be said to have 'functional malleability' (Gledhill, 1994 p 216). Hence there appears to be a sense (particularly expressed by factor-2 participants) that the term in all its ambiguity might be politically *useful* in terms of acting as a catalyst for certain kinds of discussions. Ironically the primary discourse of opposition as represented by factor 3, in its view of geoengineering as emblematic of the fundamentally flawed nature of the global neo-liberal political economy, might actually act to breathe life into it. Within the factor-1 framing, the desire to disaggregate the term might be read as an opposition to the constraints of the term, or as an example of boundary work aimed at reducing ambiguity; while the broad definition of geoengineering offered by factor-4 participants could be read as a different type of boundary work actually aimed at increasing the ambiguity of the term.

Scholte et al (2012) argue that 'ambivalence' about geoengineering is a frame in and of itself (characterised by the presentation of arguments for and against geoengineering within one text), and they suggest that the increasing prevalence of 'the ambivalence frame' above other framings of geoengineering articles in newspapers, provides hope for increasing reflexivity in the debate. We concur that ambivalence is a characteristic of the discourse as a whole, as indicated by the co-existence of multiple divergent normative positions within the debate. However, counter to the argument made by Scholte et al, ambivalence is not here understood as a singular way of framing geoengineering in and of itself. The relatively high number of so-called 'confounders' (individuals whose Q sorts correlated with more than one frame), that emerged from the analysis presented here, could be interpreted as revealing different forms of ambivalence with respect to these framings. However, ambivalence with respect to the framings described here need not correspond to an individual being ambivalent about geoengineering per se, although equally, this may be the case in some instances. The existence of these ambivalences might best be interpreted as a degree of instability in the discourse, suggesting that the meanings attributed to geoengineering are still in some senses quite negotiable. Within the four frames uncovered by this study, there emerges clear (non-ambivalent) support for, and opposition to geoengineering represented by the polarised factors 2 and 3. In addition, the positions represented by factors 1 and 4, rather than being distinguished by ambivalence, may actually be interpreted instead as clear efforts to formulate non-ambivalent positions with respect to different issues within the geoengineering discourse. For example, this may be by discriminating in more detail between particular technologies (to allow non-ambivalence on each). Or it may be through seeking to elucidate a discriminating normative position in relation to specific issues such as the controllability/knowability of the climate, the neutrality or otherwise of research, and the role of technology in society, each of which also has the effect of reducing ambivalence in particular instances.

The existence of the framing exemplified by factor 4, also problematises the frequent calls for increasing precision around the term geoengineering as a pre-requisite for effective governance discussion. This is because it highlights how no one framework for partitioning of the term geoengineering into sub-categories can in itself be thought of as final. The commonly used CDR/SRM distinction, for instance, or even to the level of 'individual' technologies, only makes sense from within particular frames. Alternative partitionings of the overarching field, like those defined under factor 4, may cross-cut such a taxonomy – and each other. So any one form of precision may reduce particular ambiguities, but leave others unaddressed – or even compound them. Calls for greater precision must therefore be interrogated as to particular axes of precision involved and their implications. And it cannot be assumed that precision in and of itself will remedy ambiguity.

Axes of difference

Hulme (2008) argues that the prospective routes held out to us for dealing with climate change all have 'connotations of global control and mastery of the climatic future' (p. 12), and this observation is borne out of the factors that emerged from this study, in which various ideas around the issue of control constitute one of the axes of difference between the framings. Unsurprisingly perhaps, the starkest contrast is between the polarised views of factor 2 and 3, although interestingly notions of control are arguably central to both, with the former affirming the notion that 'we can and should control the climate', and the latter affirming the notion that 'we can and should control the research.' Hence the factor-2 framing of geoengineering as 'planetary maintenance engineering' [6], and its emphasis on the human ability to create complex control systems [30], building on an ever increasing scientific sophistication allowing greater understanding of complexity [17]. Conversely the factor-3 framing emphasizes what is perceived to be the folly of attempts to control nature [1, 15], the irreducible complexity and chaos of the climate system [17], and human fallibility in attempting to create complex control systems in the past [30]. The roles are reversed when the focus becomes control of research and other geoengineering activities, with the factor-2 framing emphasizing what is felt to be the 'counterproductive' nature of attempts to ban on geoengineering which would result in testing carried out in secrecy [34], and the inappropriateness of a moratorium on geoengineering [25], while the factor-3 framing emphasizes the perceived necessity of strong controls on research. With regard to the degree to which this control of research is believed to be possible, one participant commented:

> 'It may be true that it's not fully enforceable but it has very powerful norm setting… it's very important to set that as the standard.'

While rejecting the 'planetary maintenance' metaphor, the factor-1 and 4 framings diverge somewhat in their view of the feasibility of achieving climate control, with more reticence being expressed within the factor-4 framing, about the possibilities for either knowledge of complexity [17], and control of the climate [30].

The concept of research represents another fault line or tension between the framings. Given that much discussion of geoengineering occurs in academic journals, and much of the discussion is about research of various types and disciplines, Geoengineering is thus framed by many as being 'at the research stage', and in particular factor 1 participants appeared to adhere to this view. Thus for example, a fairly typical factor-1 viewpoint was expressed thus:

> 'I would be paranoid and scared of anybody saying we're going to start geoengineering tomorrow, but I'd be just as worried about someone saying we're going to outlaw any research on geoengineering. We need to do this research. Whether or not we actually do anything with the research is another matter. But in case we need to geoengineer, we

> should do the research now. Because when you're doing it in a panic and you think you've only got 20 years before London is underwater, you're not going to do science as well as when you think we might not need to do this, you can actually sit back and concentrate and take a slightly longer term view of it'.

The emphasis on research is broadly shared by factors 1, 2 and 4, as illustrated by factor scores for statements 3, 12, and 33, but is problematized by factor 3 in particular, and to a lesser extent factor 4 (statements 16 and 37). Thus a factor 3 participant commented about research:

> '[research] creates a dynamic where you're moving towards something, it creates the beginnings of almost an industry of people who have invested in all of that.'

And the same participant was keen to unpick the term, asking 'what's hidden in the term research'? and commenting:

> 'I think it's a very deliberate, the term [research] gets kept together, and by being kept together it means that people who actually don't ever want to move to some kind of experimentation should nonetheless feel they have to support that statement [3] … it speaks to scientific freedom and all these kind of things, which of course and if you're in academia are deeply important and rightly so, but I think it's a deliberate strategy to keep that language obscure'.

The way in which geoengineering is framed (particularly but not exclusively by factor 1 participants) as being at the research stage, also feeds into ideas about the degree to which geoengineering represents something fundamentally new and untried, or is a continuation/the latest manifestation of practices and ideas with a long history. Of the four framings uncovered by this study, the emphasis on continuity is most apparent within the factor-3 and 4 framings, while as outlined above, 1 and 2 appear to emphasize research and novelty. For example, factor 3 was distinctive among the four factors in awarding neither a positive nor negative ranking to statement 7 (that deliberate geoengineering has been happening for decades and was not all about dealing with climate change). Interview data and comments from participants who loaded on factor 3 point to a division over exactly what this means. One view was characterised by the following comments:

> 'Geoengineering technologies patented decades ago have been and are being used covertly as political/economic/military weapons. This is obvious to anyone who studies the sky and knows the history of weather/climate modification development. Look up!'

Although not all factor-3 participants shared this view, the issue of continuity with other technologies and the idea that the issue was broader than the current climate change focus might suggest were shared. Hence another factor 3 participant commented:

> 'I do think there's other interests in geoengineering other than climate change, particularly commercial interests. I think there's an attempt to create new markets in the longer term, there is military interest… I don't think they've been spraying but I do think it's not all about climate change. There's more reasons to want to have geoengineering as a tool in the box than climate change'.

The distinction between geoengineering, weather modification and so-called 'chemtrails' theories is worthy of a brief note at this point. As a subject discussed and debated by governments, think-tanks and academics, geoengineering in all its ambiguity appears to have acquired widespread credibility as a 'serious' (Keith & Dowlatabadi 1992) scientific subject. Weather modification on the other hand, has a relatively less authoritative status, occasionally presented as a 'pseudo-science', associated with an array of more or less credible characters driven by a variety of more or less honourable intentions (Fleming 2006). While finally the 'chemtrail' theory (positing the existence of a global network of weather modification for nefarious ends), lacks credibility and authority and is widely labelled (dismissively) as a conspiracy theory. However, as this examination of the multiple framings of geoengineering has revealed, the boundaries around terms and activities are by no means clear cut or un-ambiguous, and on-going boundary work (c.f. Gieryn 1983) is required to maintain the distinction between terms in such a way as to maintain the epistemic authority of certain actors.

Interview comments from factor-4 participants reveal a view that is more explicit about the fluid and blurred nature of the boundaries between different activities:

> 'We're already geoengineering the climate … I mean we do a lot to try and change the climate system, we dam rivers, we irrigate large parts of farmland that changes the local climate, we deforest. In the western US I think there's 169 weather modification project that try to improve rainfall, China does it systematically…'

And when questioned further about the distinctiveness of weather modification from geoengineering, the same participant highlighted the continuum between them and the constructed character of notions of 'climate', by commenting:

> 'Weather is events and climate is statistics…'

The distinction between weather modification and geoengineering is also brought into question by the following comment made by a factor-1 participant:

> '[The Chinese] are raising from 70 million to 500 million a year the amount they're spending on their weather modification program, and once you get to half a billion dollars a year, you're actually talking about something that on aggregate could have a significant effect.. Assume it's effective , you're now at a stage where you're modifying local weather sufficiently over a long enough period that it's kind of like a geoengineering intervention […] I think we're going to back-step into geoengineering in that way.'

The emphasis on novelty or continuity in different framings of geoengineering is intimately connected to different framings of the interests and motivations at play, and this is another axis of difference along which the framings uncovered by this study can be seen to diverge. Again, factors 3 and 4 are united by a shared framing of the potential for non-climate change related application of geoengineering technologies, including military applications.

But beyond more radical uses of geoengineering technologies for purposes other than combating climate change, a key distinguishing characteristic of the factor-3 perspective is that geoengineering – both the technologies it comprises and the attitude it is understood to represent – is an explicitly political project. The framing of the issue is understood to be a key component of that project. As a participant explained:

> 'On the pro-geoengineering side I think there is a small core of ideologically motivated and politically smart and active people who are moving people intentionally, particularly in the whole framing game in very careful ways … while there is a lot of naivety and good intention throughout the discussion there's also some very active interests… I can see some evidence of that. That sounds conspiratorial, it's not … it's just looking at the political economy of discussions around climate change'.

Finally, various authors have noted the use of a real or hypothetical climate emergency as a powerful framing device within which geoengineering interventions are situated, and similarly the existence of a climate emergency was an important element of one of the framings (factor 2) that emerged from this study. The following comment typifies this element of the framing:

> 'The risks from the climate are infinitely worse than the risks from geoengineering, I mean that's absolutely obvious. I say infinitely because that means the end of everything, end of civilisation possibly all human life, I mean it's as serious as that […] Long term it's a catastrophe.

However, although interviews reveal that the urgency of the climate predicament is clearly important for many people, it appears that the framing of the issue in terms of emergency is being consciously rejected by all but factor-2 participants [statement 48]. For example, one factor-1 participant commented: 'I think the

whole idea of a climate emergency is really kind of counter-productive.' Another hinted at a more strategic view of framing by commenting that it was not a question of whether emergency was a reality or not, but whether or not the emergency frame was helpful for achieving particular ends:

> 'I think people are consciously stepping away from [the emergency framing] because it's become clear that different ideas about what emergency means makes the term useless… It's difficult to use emergency to promote particular actions.'

However, although emergency was rejected as a valid framing of the issue by participants that loaded on factors 1 and 4, the idea of a hypothetical future emergency still featured within these views as a rationale for research [statement 19]. Participants loading on factor 3 rejected any emergency rationale (either present or future) for geoengineering. One participant explained why he considered the climate emergency framing to be problematic:

> 'The dangerous things to do with geoengineering, is to frame it … only to be a climate discussion, because if you do then it becomes this uni-dimensional, you know, climate change has got terribly bad, we need to have a fix for it, everything gets arbitrated within this very narrow climate thing, but what your changing is the planet, or you know, large parts of it, which are much more than about climate, climate is just one factor.'

Significant silences

It is worth noting that a number of people involved with critical environmental NGO's, who were invited to take part in this study did not respond to invitations to participate, and hence it is likely that there may be a number of significant silences or gaps in the research presented. The reasons for individuals' reticence about involvement (whether about the subject matter, this particular study, or the Geoengineering Governance Project more broadly) were not specified and thus can only be the subject of conjecture. However, Walker and Shrove point out that involvement of a broad range of stakeholders in participatory projects and processes, can raise a number of issues, with the potential for inclusion to be 're-interpreted as a process of co-option and neutering of dissent, producing deeply problematic tensions for those taking part' (Walker & Shrove 2007, p.221). Indeed the issue of co-option was one that was raised explicitly by a factor 3 participant, who argued that much of the discussion around geoengineering was being manipulated by people interested in slowing down and confusing governance of climate change; and that hence even being drawn into these discussions would be to play into the hands of these interests. He commented:

> 'There's a lot of well-intentioned people, who are caught up in the discussion and I think to some extent are being used, and some of them are letting themselves be used...'

If then, one views the conversation itself as a massive distraction from existing governance discussions around climate change, then perhaps silence and non-participation in that conversation, as embodied by refusals to participate in just such processes and projects as this one, can be read as an effective form of dissent (c.f. J. Whelan & Lyons 2005).

Conclusion

Fischer and Hajer (1999, p.2) argued that although conceptually weak, the term 'sustainable development' created a generative metaphor or story-line around which different interests could converge, and thus proved to be a very functional concept. Arguably the same might be said of the term 'geoengineering' (on a smaller, subordinate and more idiosyncratic canvas). As this study has illustrated, geoengineering has a fluid and ambiguous set of meanings and is framed by different actors in a number of ways. Interestingly (and unlike 'sustainability'), the convening power of the term seems equally potent in two opposing directions. This evident polarity within the debate as revealed by the existence of factors 2 and 3, appears to indicate a 'framing gulf' across which actors are likely to 'talk past one another' rather than engage meaningfully (c.f. Hoffman 2011).

However, it is also the case that the existence of additional framings not defined purely along this axis of difference suggests an emerging resistance among certain actors to the debate becoming polarised in this way. These alternative framings appear to be seeking either to increase (in the case of factor 4) or decrease (in the case of factor 1) the ambiguity of the term, but given the multiple framings and meanings within the term, the latter is unlikely ever to be fully realizable. Unlike the picture suggested by Scholte et al. (2013), who suggest that what they call 'the ambivalence frame may prove to be less powerful than other frames that evoke strong positive or negative feelings', our findings suggest that ambivalence is not best seen as a frame in and of itself able to garner or lose support. Rather, along with ambiguity, it is a more pervasive and fundamental feature of the discursive landscape of geoengineering.

Interviews have highlighted the diversity of actors broadly ascribing to shared framings of geoengineering, which might suggest the coming into existence of various discourse coalitions (F. Fischer & Forester 1993) around the term, linking otherwise disparate actors and networks through certain shared narratives and the utilisation of certain discursive resources (e.g. the narrative of the neutrality/ normative desirability of 'research' linking disparate groups within factor 1, or the narrative of the essentially undemocratic nature of engineering at the planetary scale, linking groups within factor 3). And that the ambiguous nature and interpretative flexibility of the term facilitates this process by allowing individuals with perhaps little in common, to speak the same language or

advance shared interests. Clearly there is also a danger here of co-option of certain actors by others utilizing particular framing devices strategically to garner support for a particular view.

Finally there may be significant silences in the picture presented, and evidence of a desire for non-engagement in debates around geoengineering, which might have implications for future work on public engagement.

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Appendix: Participant list

Name	Professional self-description and discipline (where applicable)	Institution/organisation (where applicable)
Adrian Tuck	Professor, physical chemistry and meteorology	Imperial College London, UK
Andrew Lockley	Internet Marketing Consultant/ moderator of Geoengineering Google group	Business Angel consulting, UK
Andy Boston	Technical Head, Business Modelling	E.ON, UK
Angus Ferraro	PhD researcher, meteorology and climate science	Reading University, UK
Ben Parker	Post-doctoral research fellow, climate modelling	University of Leeds, UK
Catherine Scott	PhD researcher, atmospheric sciences	University of Leeds, UK
Cathy Johnson	Climate science researcher	Department for Energy and Climate Change, UK
Clare Heyward (CGG)	Research Fellow, political philosophy	Oxford University, UK
Hayley Stevenson	Lecturer, politics	Sheffield University, UK
Hiroshi Mizutani	Professor of biogeochemistry and sociogeochemistry	Nihon University, Japan
Holly Buck	PhD researcher, development sociology	Cornell University, US
James Greyson	Consultant	Blindspot thinktank & Carbon Gold, UK
Jason Blackstock (CGG)	Research Fellow/ Deputy Director, Centre for Engineering Policy, physics/policy	University College London, UK
Jim Thomas	Research programme manager	Etc Group, Canada
John Nissen	Chairman	Arctic Methane Emergency Group, UK
Jon Taylor	Climate change programme manager	WWF, UK
Jolene Cook	Researcher, climate science	Department for Energy and Climate Change, UK
Masahiro Sugiyama	Researcher	Central Research Institute of Electric Power Industry, Japan
Matt Woodhouse	Research Fellow, atmospheric chemistry	University of Leeds, UK
Max Mogren	Freelance journalist	NA
Mike Childs	Head of Policy, Research and Science	Friends of the Earth, UK
Paul Appleby	Head of Energy Economics	BP, UK
Peter Davidson	Consultant chemical engineer	Davidson technologies, UK
Peter Healey (CGG)	Research Fellow, sociology	Oxford University, UK
Phil Renforth	Research Fellow, civil engineering/geochemistry	Oxford University, UK
Piers Forster	Professor, atmospheric sciences	University of Leeds, UK
Richard Mountford	Founder/ director	2percent for the planet, UK

Roger Pielke	Professor, environmental studies	University of Colorado, US
Ronal Larson	Consultant/ coordinator of Yahoo discussion group on biochar	Larson Consulting , US
Simon Driscoll	PhD researcher, atmospheric physics	Oxford University, UK
Stephen Battersby	Science journalist	New Scientist, UK
Tim Kruger	Programme manager /James Martin Fellow, Oxford Geoengineering Programme	Oxford University, UK
Tina Sikka	Lecturer, communication	Simon Fraser University, Canada
Nils Markusson (CGG)	Research Fellow, geoengineering governance	Oxford University, UK

(CGG) indicates a participant associated with the Climate Change Governance project.