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A Review of the Social Science Literature on Climate Engineering Technologies

by Judith Kreuter

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Abstract

In public discussion, scientific publications, political debate and economic analysis alike, climate engineering is always presented in a certain way which alleviates the importance of some aspects of it and neglects others – climate engineering is framed. Frames are considered very relevant for this issue in social science literature. The aim of this paper is to discover which representations of climate engineering (CE)[1] are considered most salient, and how they are approached. The author argues that the understanding of climate engineering as (part of) a solution to the political problem of climate change is the dominant frame in the discourse on the issue. On the basis of this frame, other, more specific frames are analyzed in the literature.

[1] The terms "climate engineering" and "geoengineering" were considered to be interchangeable, and both are here defined as "deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming" (Shepherd, Cox, Haigh et al. 2009, ix). For a critical discussion of a number of definitions used in the literature, see Bellamy, Chilvers, Vaughan et al. (2012b).

1. *Introduction*

For about half a decade, climate engineering[2] (CE) is not only an object of interest for natural scientists and engineers anymore. Particularly the wide, in some cases global scope of effects of climate engineering technologies as well as their deep implications for human society make those technologies prone to analysis and evaluation by social sciences as well as humanities. The research question of this review is the following: Which representations of climate engineering are considered most salient by social sciences, and how are they approached? While the objects of interest, the research questions, the scope, the underlying theories, the methodologies and the data used in social science studies on climate engineering differ widely, one common denominator is the consciousness of the relevance of how climate engineering is framed (Rickels, Klepper, Dovern et al. 2011, 23; Wiertz 2012, 53; Cairns and Stirling 2014, 36). Here, to frame is understood as

> "to *select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation* for the item described." (Entmann 1993, 52)[3]

In public discussion, scientific publications, political debate and economic analysis alike, climate engineering is always presented in a certain way which alleviates the importance of some aspects of it and neglects others. As Mike Hulme (2014, 5) points out: "In controversial public debates it matters how terms are defined and understood." While the actual definitions of climate engineering used in different contexts show very little variance,[4] the way that the issue is framed differs according to the context, the speaker, the audience and a number of other factors. Bearing in mind this relevance of frames for social science examination of the issue of climate engineering, in this review, the literature is structured according to the level of analysis from which these frames are approached. Three larger categories structure the literature in this review, moving from the (implicit) assumption of a certain perspective to the analysis of the process of application of these perspectives to the analysis of the implications of specific perspectives: While the first category deals with analyses of proposed courses of

[2] For the purpose of this paper, "climate engineering" and "geoengineering" will be used interchangeably, as both terms are used comparably strongly in the literature reviewed here.

[3] Accentuations are taken from the original if not indicated differently.

[4] The definition introduced by the Royal Society (Shepherd et al. 2009) dividing climate engineering technologies into two basic groups – solar radiation management techniques (SRM) and carbon dioxide removal methods (CDR) – has been met with widespread acceptance, with some minor adjustments made in some papers and publications. For a critical discussion of the differences between a number of definitions used in the literature, see Bellamy et al. (2012b)

action in the face of the risks and promises of geoengineering technologies, the second and third focus more closely on the relevance of framing for the issue. The main question of analyses in the first category is how climate engineering should be dealt with. The individual frames give perspective to the analysis of this question. The second and third category go further into the analysis of the frames themselves: Literature analyzing the process of framing itself – either by studying perceptions or by examining presentations of geoengineering – were collected in the second category. The third category comprises all literature that analyzes one or a number of specific frames and issues connected with understanding climate engineering in that specific way.

While some monographs, anthologies, and policy reports have been published which attempt to give a comprehensive overview over many or all of CE's aspects and implications (Bickel and Lane 2009; Shepherd et al. 2009; Kintisch 2010; Olson 2011; Rickels et al. 2011; AAS 2012; Amelung, Dietz, Fernow et al. 2012; Burns and Strauss 2013; Hamilton 2013a; Lane and Bickel 2013; Hulme 2014), most social science literature on the topic focuses on very specific issues and questions. Thus, the third category deals, on the whole, with what climate engineering is understood to be, and which implications follow. The different analyses were structured according to their relevance to the overarching framing of geoengineering as (part of) a solution to a political problem, i.e. climate change (4.1). The consideration of CE technologies – be it from a social or a natural science perspective – is nearly always motivated and/ or justified by pointing to the potential of these technologies to help solve the political problem of climate change, which is why this is considered the overarching framing in this paper. Section 4.2 comprises literature which focuses on social implications of this idea. Section 4.3 draws together studies which analyze climate engineering from an international conflict perspective: CE technologies are found to be possible sources of conflict or additional drivers of existing conflicts. Section 4.4 comprises literature which studies implications of political interest constellations for the proposed technologies: A salient frame is that of geoengineering as a political arena – here, the notions of a 'geoclique', the issue of vested interests and the relation between knowledge and power come into play. Sections 4.5 to 4.7 contain literature dealing with CE with reference to science and technology studies, ethics, and economics, respectively.

The categorization developed here does not make any differentiation between different kinds of climate engineering technologies. It would be possible to divide all of the categories up again, into those texts that are concerned with SRM techniques and those concerned with CDR measures, or into even smaller subcategories, one for every technology proposed which fulfills the criteria of the definition for ‘climate engineering’. However, as climate engineering research in the social sciences is still comparatively young – the oldest texts considered here are from 2007 – the subdivision in too much detail does not make much sense, as one would come up with an overwhelming number of categories for a relatively small number of texts. Also, many social, economic and political issues connected with different technologies are relevant for the entirety of climate engineering measures, for example the so-called ‘moral hazard problem’ or the ‘Plan B’ framing.

2. *Analysis of courses of action*

A substantial part of the social science literature on CE deals with the question of how these technologies and their development and possible deployment should be dealt with. These analyses have been categorized here according to their focus: the public, governance/ law, and ethics. Most of these courses of action are not mutually exclusive: A number of different approaches could be combined in order to establish a comprehensive method of approaching geoengineering. The differentiation of the four areas of interest is aimed solely at clarification.

Two courses of action are analyzed and discussed with a focus on the public: the engagement of the public in the deliberation on CE and appraisals of the social consequences of these technologies. As Adam Corner and Nick Pidgeon argue, the term ‘public engagement’

> “is typically poorly specified. From purely communicative projects aimed at improving lay knowledge in some way, to consultation processes that might be more accurately described as market research, to large-scale analytic-deliberative processes involving both lay and expert participants – the concept of public engagement is broad and negotiable.” (Corner and Pidgeon 2010, 30)

Corner and Pidgeon discuss models of involving the public in decisions about science and technology and conclude “that the upstream public engagement tools that have been developed for studying nanotechnology may also be usefully applied to assess people’s perceptions of social and ethical implications of geoengineering” (Corner and Pidgeon 2010, 33). The idea of upstream engagement is to encourage public activity throughout the process of deliberating a technology, long before deployment (see Corner and Pidgeon 2010, 32). Sylvia Hiller and Ortwin Renn similarly find that “even at this early stage in the development of climate engineering, it is necessary to provide the public with background information about the topic.” (Hiller and Renn 2013, 34) The specific inclusion of the voices of the vulnerable are the focus of a study of Suarez and colleagues on the humanitarian challenge posed by geoengineering (Suarez, Banerjee and Mendler de Suarez 2013, 1). Jack Stilgoe and colleagues argue that "public engagement with biotechnologies offers lessons for the governance of geoengineering research" (Stilgoe, Watson, Kuo et al. 2013, 1). Wylie Carr, Laurie Yung and Christopher Preston call for the upstream engagement of the American public of climate engineering issues, warning, however, that "the quality of the outcome depends on the effectiveness of the process itself" (Carr, Yung and Preston 2014, 44), for example the way of presenting information on CE. The process of incorporation of geoengineering questions into public deliberations is analyzed by Rob Bellamy and Javier Lezaun (Bellamy and Lezaun 2015).

Expert appraisals are a different approach to ensure the inclusion of social considerations in dealing with geoengineering (see, for example, Amelung et al. 2012). These are, in turn, object of scrutiny to some social science literature. As Bellamy and colleagues state: "To support decision makers in the multitude of governance considerations a growing number of appraisals are being conducted to evaluate their pros and cons." (Bellamy, Chilvers, Vaughan et al. 2012a, 1) In their analysis of a number of different appraisals, they come to the conclusion that appraisals "of geoengineering can be seen to be 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. 2012a, 28) Similarly, Clare Heyward argues that deliberation of geoengineering is limited by regarding it "as a third category of response to climate change" (Heyward 2013, 23) and instead, offers a typology of five answers to climate change, two of which are CDR and SRM (Heyward 2013, 25).

The central political course of action in the face of CE is governance – both of research and development (see, for example, Dilling and Hauser 2013) and of deployment of these technologies. The scope of literature on this issue spreads from discussion of issues connected with establishing governance in this field (Cicerone 2006; Victor 2008; Lin 2009, 15ff.; Virgoe 2009; Suarez, Blackstock and van Aalst 2010; Bodansky 2012; Harnisch 2012; Leal-Arcas and Filis 2012, 132; Morrow, Kopp and Oppenheimer 2013; Bellamy 2014a; Parker 2014; Parson 2014) and general arguments on the necessity of governance (Welch, Gaines, Fonseca et al. 2012) to analyses of existing governance structures with relevance for the geoengineering case (Humphreys 2011; Proelss 2012; Bracmort and Lattanzio 2013; Hester 2013; Lin 2013b; Wirths 2013; Parson 2014; Huttunen, Skytén and Hildén 2015) or examples of specific attempts to govern geoengineering (Banerjee 2011; Macnaghten and Owen 2011; Rayner, Heyward, Kruger et al. 2013) to specific recommendations, for example the establishment of governance bodies, procedures or frameworks (Blackstock and Long 2010; Santillo and Johnston 2010; Lane 2011; Long, Hamburg and Shepherd 2012; Winickoff and Brown 2013; Zürn and Schäfer 2013; Lloyd and Oppenheimer 2014). The latter include such different ideas as the establishment of a classical international organization for governance and regulation on one side of the spectrum and scientific self-governance approaches on the other.

A number of issues, problems and challenges are being discussed concerning the establishment of governance in the field of CE: David Morrow and colleagues attempt to find out how political legitimacy in decisions about geoengineering can be achieved (Morrow et al. 2013, 146), applying Allan Buchanan and Robert Keohane's Complex Standard of legitimacy to the case of CE (Morrow et al. 2013, 150). Daniel Bodansky approaches the issue from a similarly theoretical perspective, analyzing the purpose, possible forms and agents of CE governance (Bodansky 2012, 4, 8+9). He finds that "[g]overnance is needed […] to ensure sufficient geoengineering and […] to avoid too much." (Bodansky 2012, 4) Andy Parker critically examines the potential of a moratorium on research until governance has been established, finding that it would be "ineffective and […] counterproductive" (Parker 2014, 1). Edward Parson analyzes four different ways in which a linkage between CE and mitigation can be established to "enhance mitigation incentives" (Parson 2014, 89) and to "make the two approaches complementary" (Parson 2014, 104). Bellamy and colleagues make the argument that attempts at governance of geoengineering are moving in the wrong direction and that it needs to be "opened up" (Bellamy, Chilvers, Vaughan et al. 2013), for example to considerations of technological foresight, context and robustness (Bellamy 2014a, 13, 17+19). Jesse Reynolds makes predictions on climate engineering governance, drawing from the case of nuclear energy, which he considers to be "the best existing case in international law from which to draw insights into the potential regulation of climate engineering and its research." (Reynolds 2014b, 275) He finds that "climate engineering research will most likely be promoted and will not be the subject of a binding multilateral agreement in the near future." (Reynolds 2014b, 269) Nils Markusson and Pak-Hang Wong criticize that the geoengineering governance discourse is mostly based on the "linear conceptualisation [sic] of technical innovation" (Markusson and Wong 2015, 4) and argue for a governance framework that factors in the non-linear character of technical innovation, namely that of technology accompaniment introduced by philosopher Peter-Paul Verbeek (Markusson and Wong 2015, 13) Rider W. Foley, David H. Guston and Daniel Sarewitz offer the framework of "anticipatory governance" (Foley, Guston and Sarewitz 2015, 2) to evaluate and manage emerging technologies. Stilgoe argues that geoengineering can be understood as a social experiment and offers the opportunity to "approach a new mode of governance – collective experimentation" (Stilgoe 2015, 1) of CE, which would include not only scientists, but also publics, politics and ecosystems.

When it comes to the analysis of existing regimes, a number of different mechanisms of international law are discussed which are not aimed at geoengineering, but have implications for it nonetheless (see, for example, Shepherd et al. 2009, 39; Bodansky 2011, 13ff.; Rickels et al. 2011, 95; Lin 2013b, 182; Reynolds 2015, 5). Among those are the precautionary principle of the Rio Declaration (Humphreys 2011, 106; Proelss 2012, 206), the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) (Davies 2009, 3; Humphreys 2011, 107; Wirths 2013, 425; Parson 2014, 96; Reynolds 2015, 7), the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies (Outer Space Treaty) (Humphreys 2011, 107), the Montreal Protocol (Humphreys 2011, 107; Parson 2014, 95), the United Nations Convention on the Law of the Sea (UNCLOS) (Davies 2009, 3; Humphreys 2011, 108; Proelss 2012, 205; Wirths 2013, 426; Parson 2014, 97; Reynolds 2015, 8), the London Convention and Protocol under the International Maritime Organization (Proelss 2012, 205; Wirths 2013, 427; Parson 2014, 96; Reynolds 2015, 8), the Convention on Long-Range Transboundary Air Pollution (CLRTAP) (Proelss 2012, 426; Wirths 2013), the Convention on Biological Diversity (CBD) (Subsidiary Body on Scientific Technical and Technological Advice 2012) and, perhaps most importantly, the Framework Convention on Climate Change (UNFCCC) (Davies 2009; Banerjee 2011, 18; Humphreys 2011, 108; Proelss 2012, 205; Wirths 2013, 424; Reynolds 2015, 6). While the relevance of existing mechanisms and regimes for the governance of geoengineering is recognized, their reach is commonly deemed insufficient to meaningfully cover all the governance needs of the geoengineering case (see, for example, Victor 2008, 322; Banerjee 2011, 35; Humphreys 2011, 115; Lin 2013b, 182; Wirths 2013, 437; Parson 2014, 95). Suvi Huttunen and colleagues analyze policy documents from the governments and other political bodies in a number of countries as well as from international governmental and non-governmental organizations in order to "gain insights into how geoengineering is perceived at the policy level" (Huttunen et al. 2015, 1).

There have been some attempts at creating regulations to specifically govern geoengineering research: among those are the Oxford Principles (Rayner et al. 2013), a set of five principles put forth by an ad-hoc group of scientists in answer to in inquiry by the UK

House of Commons Select Committee on Science and Technology (see Rayner et al. 2013, 2), as well as the Solar Radiation Management Governance Initiative (SRMGI) (Long et al. 2012; Dilling and Hauser 2013; Hanafi and Hamburg 2013), which was established by the Royal Society in cooperation with the World Academy of Sciences and the Environmental Defense Fund. SRMGI's principles were the basis for the cancellation of the contentious Stratospheric Particle Injection for Climate Engineering (SPICE) project (Long et al. 2012, 323; Stilgoe et al. 2013, 2; Winickoff and Brown 2013, 80) launched in the United Kingdom. Based on an analysis of the SPICE project, Phil Macnaghten and Richard Owen assert that for "geoengineering technology to progress, […] it must proceed under robust governance mechanisms." (Macnaghten and Owen 2011, 293) The way in which the geoengineering issue is treated by the Intergovernmental Panel on Climate Change (IPCC), an influential body of scientists and governments, is the subject of Arthur Petersen's examination, who finds that "geoengineering has […] never been endorsed by the IPCC" (Petersen 2014, 3), but that in order to reach the two-degree target, negative emissions – such as those created by some CDR techniques – would be needed.

Other ideas are proposed for the governance of geoengineering research and deployment, such as the production of norms and best practices by scientists (Blackstock and Long 2010, 527), the incorporation of CE regulations into existing regimes (Wong, Douglas and Savulescu 2014, 19) like the UNFCCC (Barrett 2009, 21) or the building of a dedicated climate engineering regime (Lane 2011, 5; Winickoff and Brown 2013, 81; Zürn and Schäfer 2013, 273; Lloyd and Oppenheimer 2014, 53). A range of approaches and proposals to govern geoengineering are compared and critically analyzed by Banerjee (2011), who examines "the limitations of voluntary codes of conduct and treaties, the most popular approaches to governing geoengineering" (Banerjee 2011, 15). David Santillo and Paul Johnston agree that voluntary codes of conduct are insufficient and that to "be truly effective in serving the needs of governments and civil society, such a governance system must be mandatory, international and ultimately global in scope" (Santillo and Johnston 2010, 6).

Questions concerning ethical norms and rules which could help to deal with geoengineering are raised by a number of authors. David Morrow, Robert Kopp and Michael Oppenheimer "propose three ethical guidelines for CE researchers, derived from the ethics literature on research with human and animal subjects, applicable in the event that CE research progresses beyond computer modeling" (Morrow, Kopp and Oppenheimer 2009, 1). These three norms are respect for persons, beneficence and justice, and minimization (see Morrow et al. 2009, 4-

6). Heyward analyzes “how to organize compensation or redress for any adverse impacts that could not have been predicted at the time of deployment” of CE and argues that “with some modification, the principle that agents should surrender benefits that have accrued to them from using geoengineering techniques, can be a good basis for such a scheme” (Heyward 2014, 1). According to Forrest Clingerman and Kevin J. O’Brien, religion should be included into the debate on CE, particularly because it plays an integral part in the lives of many people and because it offers “vocabulary for moral debate” (Clingerman and O'Brien 2014, 27).

3. *How is climate engineering presented and understood?*

While in the analysis of different courses of action, a certain frame is accepted, in other social science publications, the development and occurence of frames is analyzed. These publications are summarized in the following chapter.

3.1 Public perceptions of climate engineering

The relevance of public perception is underlined already by the influential and comprehensive report on climate engineering by the British Royal Society published in 2009: “It is clear that public attitudes towards geoengineering […] will have a critical bearing on its future.” (Shepherd et al. 2009, 59) The authors find that “[p]erceptions of geoengineering proposals are generally negative, but are complex and method-specific.” (Shepherd et al. 2009, 59) When climate engineering is viewed as a public issue, it is of interest to researchers how the public views this issue, how it approaches it and what factors these perceptions and approaches depend on. Findings from a number of studies show that, so far, knowledge about the issue is not wide-spread, but that negative and critical outweigh positive and enthusiastic attitudes. The way people perceive geoengineering depends on how the issue is presented – through natural analogues, as an alternative to mitigation, or as a research program rather than a deployable measure, for example. Also, the level of awareness as well as the degree of acceptance of geoengineering differs between the US, the UK and Germany. Studies on public perception outside the Western context have been neglected in the literature thus far. This corresponds with the scientific interest in the issue, which is particularly strong in the US and other English-speaking Western countries (Belter and Seidel 2013, 422).

The public opinion on geoengineering in the UK is well-studied: An early public opinion study conducted by the National Environment Research Council of the United

Kingdom in 2010 brought together members of the public in group discussion sessions. The conveners found that "[a]wareness and knowledge were low prior to the session", but that they increased during discussion, and that none of the participants were "vehemently against all geoengineering approaches as a matter of principle" (NERC 2010, 1). A group of social scientists around Pidgeon, Corner and Karen Parkhill (Pidgeon, Corner, Parkhill et al. 2012) analyzes the early responses of the UK public to geoengineering. Their data – from interviews and surveys – originates from 2009 and onwards, early even in the scientific debate on climate engineering[5], and thus, the public awareness that they find is very low. Acceptance of climate engineering technologies is correlated, according to their findings, with the type of technology proposed – CDR measures enjoying more acceptance than SRM – as well as the level of concern with climate change issues shown by the interviewee. Another study by nearly the same group of researchers reports findings from deliberative workshops "conducted with members from the UK public during early 2012" (Corner, Parkhill, Pidgeon et al. 2013, 938) with the aim of identifying central ideas connected with climate engineering. The scientists find that the idea of 'messing with nature' most strongly influenced how the participants thought about the issue. Concerning one prominent argument regularly expressed against geoengineering, Corner and Pidgeon find that "the moral hazard argument against geoengineering was perceived more convincing overall than a counter-argument" (Corner and Pidgeon 2014, 11) by the UK public. From a study with focus groups, Phil Macnaghten and Bronislaw Szerszynski find that the "question of how to bring into democracy these issues [sic] […] will have to be carefully and systematically considered in advance of any discussions of solar radiation management deployment." (Macnaghten and Szerszynski 2013, 472) Focus groups in Sweden were interviewed by Victoria Wibeck, Anders Hansson and Jonas Anshelm, who found that "social representations [of CE] started to form […] through testing and negotiating arguments pro and contra […] research and deployment." (Wibeck, Hansson and Anshelm 2015, 23)

[5] The origins of the debate on climate engineering are difficult to date: Some measure of climate and weather modification has always been part of human culture, whether in the shape of esoteric phenomena like rain dances and witchcraft or as scientific technology. Modern climate engineering stems from the Cold War era, when the tensions between the USA and the USSR brought forth attempts at modifying climate and weather in order to utilize them as weapons against the enemy (Fleming 2010, 165ff.). And while this period of human history also witnessed first calls for climate engineering as a countermeasure to disadvantageous influences of human activity on the climate (Fletcher 1969; Budyko 1977), enthusiasm for these technologies somewhat waned after the end of the Cold War and the disenchantment with fundamentally powerful technologies such as nuclear weapons. The renaissance of climate engineering research is commonly attributed to a seminal contribution by Crutzen (see, for example, Kerr 2006, 401) who argued that global political efforts have not yielded the necessary changes in emission behavior, and that an alternative, namely climate engineering, needed to be brought back onto the table (Crutzen 2006, 211-212). Accordingly, this paper considers the beginning of the current climate engineering debate to be in 2006.

The German public perception of geoengineering has also been subject of scrutiny: Drawing on the results from an expert delphi, Wilfried Rickels and colleagues (2011) find that there are a number aspects of the issue that are relevant for its perception in the public: Climate engineering is a technologically very complex issue, which makes it prone to scientific uncertainties. Additionally, some aspects of it just cannot be known yet, even by the savviest scientists, as they lie in the future, and thus, in addition to scientific uncertainties, 'deeper' uncertainties prevail. In addition to these uncertainties, climate engineering bears a strong potential for social conflict (for example due to issues around the allocation of goods) and the general trust of the public in technology is considered to be at an all-time low. Surveys cited by Rickels et al. from the US, the UK, and Germany indicate that, while big parts of the public have not heard of climate engineering – with numbers rising due to strengthening media interest in the issue –, those who have share a rather negative attitude towards it. However, the authors conclude that "the future of the CE debate and its acceptance in the population"[6] is still mostly undecided (Rickels et al. 2011, 92).

In a similar vein, Hiller and Renn assume that "the majority of the German population either have no opinion on geoengineering or view it with caution and skepticism" (Hiller and Renn 2012, 217). Based on an analysis of international media articles, the authors find that the media interest in the issue is "much less pronounced in Germany" (Hiller and Renn 2012, 217) than in the UK or the US. Dirk Scheer and Ortwin Renn find that a number of studies on public perception "show low levels of awareness and a lack of knowledge" concerning geoengineering (Scheer and Renn 2014, 4). They conclude that "existing attitudes on geoengineering can be judged instable and stimulus-dependent" (Scheer and Renn 2014, 1). However, they also find that approval of geoengineering depends on whether those technologies are approached in isolation or if they are presented as an alternative to mitigation, the latter causing approval rates to decrease. Furthermore, research into geoengineering technologies enjoys more support than deployment, according to this study (see Scheer and Renn 2014, 5).

Rose Cairns and Andy Stirling (2014) use a more international approach and study the opinions on geoengineering of thirty-five participants from different professional backgrounds (academia, industry, government, non-governmental organizations and the media), located in the UK, US, Canada and Japan. They find that "geoengineering has a fluid, ambiguous and multivalent set of meanings and is framed by different actors in a variety of ways." (Cairns

[6] Translated from German by the author; original quote: „Zusammenfassend lässt sich festhalten, dass die Zukunft der CE-Debatte und ihrer Aufnahme in der Bevölkerung noch weitgehend offen ist." (Rickels et al. 2011, 92)

and Stirling 2014, 36) This sets the stage for a strong polarity, as the term allows for framing in opposing directions: for and against geoengineering.

While the studies on public perception of geoengineering do not cover more than a fraction of the world's population, they share a number of important findings concerning climate engineering as a public issue: First, public awareness of climate engineering is low. Second, existing opinions on the topic are rather cautious, critical or negative. Third, the way that the issue is framed in the media, politics and by science has a strong influence on how it is perceived by the public. Why people react to geoengineering the way they do is analyzed from a psychological perspective by Gareth Davies, who argues that "the most plausible explanation for the degree of opposition to geoengineering, even to research into it, is the need that it creates for adjustments to views of the world, and the political, social, and ultimately emotional costs that such adjustments would entail." (Davies 2013, 76)

Descriptive studies on the perception of geoengineering in the public often conclude with either describing or voicing calls for a stronger involvement of the public in decision-making procedures on climate engineering (see, for example, Shepherd et al. 2009, 60; Porter and Hulme 2013, 342). These have been dealt with in the first category, which deals with recommended courses of action.

3.2 Framing of climate engineering

The analysis of public perception of geoengineering stresses the relevance of framing in the context of geoengineering once again. This chapter is dedicated to the question of which frames exist in this context, and where they are found. The next chapter will deal with individual frames and their implications. Framing of CE analyzed in the literature takes place in the media, in scientific publication, and political debate (see, for example, Cairns 2013; Markusson 2013; Bellamy 2014b; Huttunen and Hildén 2014; Uther 2014). The studies on this issue isolate a number of frames used to explain and describe CE technologies, for example the 'insufficient mitigation' frame, the 'climate emergency' frame or the 'only option' frame. The influence of different frames on public perception is also subject of scrutiny. This chapter is dedicated to literature on the process of framing itself, while analyses of individual frames will be covered in the next section.

The argumentative structure of the debate on climate engineering in all its arenas is the focus of a chapter of the study on CE commissioned by the BMBF (Rickels et al. 2011).

While arguments[7] are different from frames and the argument mapping does not depend on whether these arguments actually do appear in the debate, the argument mapping method of this study indicates some frames used in the climate engineering debate. Frames used to describe climate engineering, according to this study, are technological research – in general as well as specifically into CE – as a human activity prone to produce unintended consequences (Rickels et al. 2011, 27), CE as a political solution due to political deadlock and the need to hold the 2° limit (Rickels et al. 2011, 28 + 30-31), and CE as a potential trigger for international political conflict (Rickels et al. 2011, 34). Gary Bowden traces the development of the climate engineering discourse, which starts out in exclusively scientific circles, where it is marginalized due to issues of "cost, feasibility, uncertainty, and risk" (Bowden 2010, 70), but then re-embraced and introduced into public and political discourse. This move is framed as "scientists and engineers […] [taking] over […] of the politicians are unwilling to step up to the plate" (Bowden 2010, 75).

Assessments of the advantages and disadvantages of CE are the focus of Bellamy (2013), who analyses the criteria according to which individual technologies assessed and evaluated.

> "[a]ssessments of geoengineering have so far largely taken place under two dominant problem definitions. First, that efforts to reduce greenhouse gas emissions will not be enough to tackle climate change ('insufficient mitigation'). Second, that as a result of this, we may be faced with a dangerous change in climate, often stylized as crossing one or more 'tipping points' (a 'climate emergency')." (Bellamy 2013, 1)

These frames are privileged, according to Bellamy, because of the mostly scientific and technical manner in which climate engineering is dealt with in assessments. Experts and political advocates alike are at the center of Tina Sikka's study on the framings used in CE advocacy in "speeches, articles, research, media submissions and policy reports given by a variety of organizations and individuals supportive of geoengineering" (Sikka 2012a, 167). She concludes that two frames in particular are salient. One is what she calls 'exceptionalism': the idea that climate change is such a catastrophic problem that CE is the "only option" (Sikka 2012a, 167) to deal with it. The other framing connects CE with economic prosperity, "positioning opposition to geoengineering as opposition to the economy" (Sikka 2012a, 170). Two more frames that Sikka isolates consider CE in terms of a technology: that of "a claim to scientific neutrality" and that of "technological determinism" (Sikka 2012a, 167). Suvi Huttunen and Mikael Hildén study the framing of geoengineering by

[7] An argument is understood here as „an attempt to present evidence for a conclusion" (Groarke 2011, part 2). Both arguments and frames commonly have the shape of statements, and an argument can serve as a frame, but does not necessarily do so.

researcher and find that three frames are prevalent: risk-benefit, governance, and natural balance-frames (see Huttunen and Hildén 2014, 3). Corner and Pidgeon analyze the framing climate engineering by drawing analogies to nature. They find that participants of an online survey in the UK are more prone to have a positive attitude towards climate engineering technologies when they are presented in terms of natural analogies such as presenting stratospheric aerosol injections as "no different to a volcano" or comparing carbon capturing chemical vents with "artificial trees" (Corner and Pidgeon 2015, 5). Bronislaw Szerszynski and Maialen Galarraga take a critical look at the sources of these frames when they analyze "the way that problem definitions are shaped by disciplinary ways of thinking and describing the world", finding that "certain disciplines are given the task of problem definition and others – typically the social sciences – are allocated the task of filling in gaps within that given frame" (Szerszynski and Galarraga 2013, 2817).

In the British media, a number of frames are used to present geoengineering according to Kate Porter and Michael Hulme: "Innovation, Risk, Governance and Accountability, Economics, Morality, Security and Justice" (Porter and Hulme 2013, 342). They point out that, rather than being issue-specific, these frames draw from the wider cultural context of the relationship between nature and man, and that they "amplify different priorities and values" (Porter and Hulme 2013, 342). Matti Luokkanen, Suvi Huttunen and Mikael Hildén analyze the use of metaphors in the two newspapers The Guardian and The New York Times in relation with geoengineering. They ascertain that metaphors of fight and war, of control, of analogies with natural phenomena and of man-made mechanisms each achieve about the same number of occurrences, with metaphors of health coming up close behind (Luokkanen, Huttunen and Hildén 2014, 972). Similarly, Brigitte Nerlich and Rusi Jaspal find that, in English-language newspaper articles, geoengineering is framed mainly in terms of three master-metaphors: "'The planet is a body', 'The planet is a machine,' and 'The planet is a patient/ addict'" (Nerlich and Jaspal 2012, 131). From an analysis of "elite English-speaking newspapers and those with high circulation rates" (Scholte, Vasileiadou and Petersen 2013, 5), Samantha Scholte and colleagues conclude that there is "strong support for an opening of the debate […] given the decline of overly deterministic frames, the emergence of frames related to sociopolitical issues and an overall more balanced distribution of the various frames." (Scholte et al. 2013, 1) A more multi-linguistic approach is pursued by Jonas Anselm and Anders Hanson, whose analysis comprises newspaper articles on geoengineering in English, German, Swedish, Danish, and Norwegian. They find that only 8% of the articles were critical of the issue, and isolate the concerns raised: the fear of a "technological gamble with the planet", the "inability to handle structural dysfunction", the "geoclique" furthering the "Trojan horse" of geoengineering to promote their personal interests and the fear of a "democratic deficit" (Anshelm and Hansson 2014a, 137-140). In a more recent publication, the authors analyze international news coverage on climate engineering using discourse analytical methodology. They find "four coherent storylines that represent most of the geoengineering advocacy in the public discourse in mass media." (Anshelm and Hansson 2014b, 101) These four storylines, they call "the scientist's double fear" (ibid., 107), "the failure of politics and cynical industrial fatalism" (ibid., 110), "pure technology: a bridge to a sustainable future" (ibid., 112) and "just mimicking nature" (ibid., 113).

While parts of the global public have been covered by the studies that have been conducted to date, wide regions remain unanalyzed: The main geographic focus of existing studies on perception and framing of geoengineering is the English-speaking part of Western society, with some detours into European societies of other native languages. While the findings of these studies are illuminating, a more comprehensive analysis is needed.

4. *Analysis of specific frames*

The literature engaged in isolating the frames that are used in different contexts in order to present the issue and how this is done indicates that, generally, CE is dealt with as (part of) a solution to the political problem of climate change. A number of studies focus on one or a few certain frames, some explicitly, some more implicitly, and analyze issues related to them, like the implications of using them or certain problems in understanding CE in these specific ways. The understating of CE as (part of) a technical solution to a political problem is considered to be the overarching framing in this paper. All other framings target certain prerequisites or implications of this notion.

4.1 The overarching framing: CE as (part of) a solution to the political problem of climate change

When climate engineering technologies are framed as the content of a policy or (part of) a solution to a political problem, theoretically, one could theoretically apply one of two perspectives: Either consider CE as a full-blown policy option in its own right, on an equal footing with measures like mitigation and adaptation, or understand CE as a necessary evil which needs to be deployed because other measures have failed or are doomed to fail. Hardly any researcher, be it from a social or a natural science background, argues for the development and deployment of CE measures without indicating that these present a necessary evil in the face of decades of inaction in the fields of mitigation and adaptation. The notion of CE as a 'Plan B', a measure of last resort or a necessary evil originated in natural science literature, (see, for example, Launder and Thompson 2008, 3841; Caldeira and Keith 2010, 57; Lane 2010, 45+48), and can be found most famously in a seminal contribution by meteorologist Paul Crutzen in 2006 which is commonly considered the turning point after a tacit taboo on geoengineering considerations (see, for example, Preston 2012b, 2; Keith 2013, 92): "By far the preferred way to resolve the policy makers' dilemma [of climate warming, author's note] is to lower the emissions of the greenhouse gases. However, so far, attempts in that direction have been grossly unsuccessful." (Crutzen 2006, 211+212). Also, the understanding of CE as (part of) a solution to a possible climate crisis is mentioned in the final draft of the 2014 report of Working Group III of the IPCC: "[Risk management] strategies require preparing for possible extreme climate risks that may implicate the use of geoengineering technologies as a last resort in response to climate emergencies (limited evidence, low agreement)." (Victor, Zhou, Ahmed et al. 2014, 5)

While the notion surfaces in nearly every paper on CE technologies, there are a number of studies putting a particular focus on discussing CE as a policy option (see, for example, Barrett 2009, 3; Bickel and Lane 2009; Blackstock, Battisti, Caldeira et al. 2009; Victor, Morgan, Apt et al. 2009, 65; Allenby 2010, 1; Bickel 2010, 31; Blackstock and Long 2010, 527; Borick and Rabe 2012, 1; Heyward and Rayner 2013b, 3; Lane 2013, 115; Michaelson 2013, 81; Gawel 2014, 2; Zhang and Posch 2014, 391). For example, Erik Gawel asks whether climate engineering could be a viable policy option, adding: "And can they serve, at the very least, as the *ultima ratio* if all other efforts to stave of climate change fail?" (Gawel 2014, 2) Jay Michaelson finds that

> "few believe that sulfuric sunscreens and ocean algae farms are *preferable* to traditional GHG reduction policies. Rather, the claim is that geoengineering is *necessary* because of the unfortunate political economy of GHG reduction, in which the highest costs of mitigation fall precisely on some of the most powerful political actors." (Michaelson 2013, 81+82)

Similarly, Scott Barrett asserts that "geoengineering, like adaptation, is an imperfect substitute for emissions reductions" (Barrett 2009, 7), adding that it might become necessary anyhow if atmospheric CO_2 concentrations are not reduced (Barrett 2009, 23). David Victor and colleagues argue: "It is […] likely […] that serious study will reveal the many dangerous side effects of geoengineering, exposing it as a true option of last resort." (Victor et al. 2009, 75) Hans Schellnhuber considers the possibility of a 'reacceleration' of global emissions, concluding: "Therefore, the last best hope may reside in an environmental fix engineering independently of energy systems transformation, namely radiation management that cools down the planet." (Schellnhuber 2011, 20277) But not only in peer-reviewed journals is CE as a policy option discussed: Christopher Borick and Barry Rabe from the US-American think tank Brookings state: "Among the options beyond mitigation through emissions reduction [to deal with climate change] are increased efforts to adapt to a warmer planet and the exploration of methods to reduce global temperatures through engineering techniques." (Borick and Rabe 2012, 1) Clare Heyward and Steve Rayner take a step back and analyze the framing of CE as a policy option: They "trace […] the development of geoengineering discourses and highlight […] the technocratic overtones of the previous climate change and environmental discourses that facilitated the advent of geoengineering research as a serious policy option." (Heyward and Rayner 2013b, 3)

The literature discussed in the following sections picks up the understanding of CE as (part of) a solution to the political problem of climate change, but focuses on distinct aspects of the issue, such as social implications or ethical considerations.

4.2 Reference to society: Climate engineering as a shield against or a source of detrimental social change

With reference to social and political implications, the climate engineering option is commonly framed in one of two general ways: either as a safeguard for society, a protective mechanism to shield it against disruptions due to unmitigated physical climate change, or as a driver of detrimental social dynamics in its own right. The idea of safeguard appears in the literature in a number of different shapes: the notion of geoengineering as an emergency measure, an instrument of last resort, a Plan B or an insurance policy are all specifications of this set of frames (see, for example, Kintisch 2010, 32+39). Dangers of geoengineering as a safeguard are presented as the moral hazard or risk compensation problem and the slippery slope argument. All of these frames share the same justification: Society is in danger because of climate change, and CE can serve as a protection against this danger. Frames in this category are isolated as a recurrent theme in discourse on CE in several studies, both empirical and theoretical (Hale 2012, 113; Nerlich and Jaspal 2012, 135; Hamilton 2014, 18; Luokkanen et al. 2014, 972).

The Plan B framing (Bodansky 2011, 5; Hulme 2014, xi; Luokkanen et al. 2014, 972; Weili and Ying 2014, 1) presents geoengineering as "an alternative or fall-back option that can be turned to if plan A fails or becomes otherwise unavailable" (Corry 2014, 4). Olaf Corry isolates other characteristics of a Plan B: According to his findings, "Plan B must initially be a less preferred option than plan A but must also be assumed to be feasible if and when the preferred option fails." (Corry 2014, 4) This Plan B framing, particularly the idea that CE is undesirable, is challenged by Davies, who argues that "it is not yet possible to argue that geoengineering is part of the solution to climate change, but the widespread assumption that it is relatively undesirable is without basis too." (Davies 2010, 262)

Clive Hamilton[8], among others (see, for example, Burns 2013, 218; Gardiner 2013a, 28; Horton 2015), elaborates upon the notion of 'climate emergency' as an argument for the development and deployment of CE technologies: "The Earth's climate is a 'non-linear system, that is, changes in one variable do not lead to simple proportional changes in related ones […] In non-linear systems, a small change in one state may initially have only small effects but at some point a threshold may be crossed where the system, driven by amplifying feedbacks, flips suddenly into a new state." (Hamilton 2013a, 12) This new paradigm of "abrupt climate change" (see also Hulme 2003; Hamilton 2013a, 13) is based on the identification of certain tipping points in the global climate system (Lenton, Held, Kriegler et al. 2008, 1786) and is, according to Hamilton, in turn the basis for the idea "that within the next few decades, we may face a 'climate emergency'" (Hamilton 2013a, 13). Gardiner argues: "Humanity stands on a precipice. Mainstream science tells us that climate change is real, accelerating, and might credibly result in global catastrophe." (Gardiner 2013b, 11) The similar idea of CE as a measure of last resort is discussed by David Victor and colleagues with reference to "doomsday scenarios" brought up by scientists, which "would dramatically accelerate and compound the consequences of global warming" (Victor et al. 2009, 64). From the focus of several natural science research institutions' workshops on CE, Hamilton draws the conclusion that "[t]he prospect of rapid deployment of a solar shield in the face of a 'climate emergency' has begun to attract serious consideration." (Hamilton 2013a, 153) The crisis or emergency framing is used to justify the scientific investigation of geoengineering technologies: Heyward and Rayner argue that the "[c]limate emergency rhetoric put geoengineering on the climate policy agenda by suggesting that scientific investigation geared towards sufficiently high impact events was justified, even imperative." (Heyward and Rayner

[8] While Clive Hamilton is not a social scientists, but a philosopher, his contribution was deemed too relevant for the topic of climate emergency to be neglected here.

2013a, 28) As Michaelson puts it: “As climate becomes more ineluctable, geoengineering becomes inevitable.” (Michaelson 2013, 83) Similarly, Davies argues: “The possibility of geoengineering-induced climate catastrophe is unattractive, but more attractive than its global warming-induced probability.” (Davies 2013, 64) Kerstin Güssow and colleagues agree that “given the large uncertainties in current climate sensitivities, we cannot rule out situations in which large-scale sink enhancement projects may be justifiable and may be applied to prevent dangerous atmospheric peak concentrations.” (Güssow, Oschlies, Proelss et al. 2013, 243) Wil Burns points out: “[…] in the past few years, the feckless response of the world community to burgeoning greenhouse gas emissions has led to increasingly serious consideration of geoengineering as a potential means to avoid a ‘climate emergency’, such as rapid melting of the Greenland and West Antarctic ice sheets, or as a stopgap response to buy time for effective emissions mitigation responses.” (Burns 2013, 200+201) Shinichiro Asayama argues that the emergency argument is part of what he calls “apocalyptic catastrophism” (Asayama 2014, 89): “The fear of future impacts of a changed climate rather than a changed climate *itself* legitimizes the option of geoengineering. As such, what underlies the idea of a ‘techno-fix’ through geoengineering is catastrophism that imagines the future climate as the apocalypse.” (Asayama 2014, 90)

The dangers of the emergency framing have been elaborated upon in several studies: Corner and colleagues find that “presenting geoengineering to people as a possible response to a climatic emergency is problematic, especially linked to the need to conduct research at an early stage: It provides a very strong framing of necessity, which is likely to have artificially enhanced the acceptability of conducting research into these technologies.” (Corner, Parkhill and Pidgeon 2011, 13-14) Similarly, Hulme identifies several problems with the climate emergency frame: “Most obvious is the problem of defining, detecting and announcing a climate emergency. What exactly *is*, or what *could* be, a climate emergency, and who is authorized to define one?” (Hulme 2014, 23) Additionally, according to Hulme, the language of emergency creates a self-fulfilling prophecy, because invoking an emergency creates an emergency, and there are certain interests at play when this invocation of a climate emergency takes place. As early as 2008, he isolates the discourse of fear which revolves around the frame of climate as a catastrophe or an emergency and traces its origins back in human history. He concludes that the attempts at controlling the climate through engineering stem from the catastrophe framing and that other ways of thinking should be encouraged (Hulme 2008, 5). Similarly, Markusson and colleagues conclude that “the emergency frame is not likely to go away, that ignoring or repressing it is a dangerous response and that more effort is required to defuse and disarm emergency rhetoric." (Markusson, Ginn, Ghaleigh et al. 2014, 281) They suggest that one major danger of this framing is that it tends to "close down rather than open up space for deliberation" (Markusson et al. 2014, 281).

The danger of the introduction of geoengineering out of fear of a looming climate crisis is addressed in the literature. What is missing in the discussions of the climate emergency argument, however, is a discussion of *how* the talk of a situation like climate change in terms of 'emergency' or 'crisis' can lead to the development and deployment of an extraordinary measure like geoengineering.

The category of geoengineering as a driver of social dynamics in its own right presents a set of frames which is the mirror image of the one before: Instead of the protection against social disruption, in this setting, CE technologies are themselves considered as drivers of social dynamics. Frames in this set are the notion that CE technologies are inherently supportive of a certain form of social organization and the notion that CE technologies will influence how societies view the necessity to mitigate and adapt to climate change.

James Fleming considers the history of climate engineering and weather modification in order to draw conclusions about potential social implications of geoengineering (see Fleming 2007; 2010; 2012; 2013). He claims that "many weather and climate engineers thought they were the 'first generation' to think about these things and, since they faced 'unprecedented' problems, were somehow exempt from historical precedents. One the contrary, they were critically in need of historical precedents." (Fleming 2010, 267) Drawing on examples like Irving Langmuir's cloud seeding experiments during the Cold War (Fleming 2010, 170) or military undertakings such as Project Popeye or Operation Motorpool (Fleming 2010, 179), Fleming points out the danger of scientific progress without public responsibility (Fleming 2010, 154pp). Quoting geoscientist J.F. MacDonald, "the key lesson of the Vietnam experience was not that rainmaking is an inefficient means for slowing logistical movement on jungle trails but 'that one can conduct covert operations using new technology in a democracy without the knowledge of the people'." (Fleming 2010, 182) Similarly, Noah Byron Bonnheim concludes that "[p]athologies of hubris are consistently present in the history of weather and climate modification" (Bonnheim 2010, 896) and calls for the integration of "social considerations with technical promise, and scientific study with human and moral dimensions" (Bonnheim 2010, 891).

Joel Wainwright and Geoff Mann go a step further and give an outlook on how society could actually change through climate engineering. They suggest that "the challenge of climate change is so fundamental to the global order that the complex and manifold reactions to climate change will restructure the world […]" (Wainwright and Mann 2012, 4) along four paths, depending on whether "the value-form will continue to shape social and natural life" (Wainwright and Mann 2012, 4) and "whether a coherent *planetary sovereign* will emerge or not" (Wainwright and Mann 2012, 4+5). Climate engineering, in this understanding, would serve as 'Leviathan's lifeblood': the stuff that keeps things running in a capitalist world with a planetary sovereign.

Another outlook of the influence of CE technologies the structure of society is given by Szerszynski and colleagues, who argue that SRM techniques are "likely to pose immense challenges to liberal democratic politics" (Szerszynski, Kearnes, Macnaghten et al. 2013, 2809). Based on Langdon Winner's understanding of inherently political technologies like nuclear weapons, which require certain social conditions like centralized chains of command (Winner 1980, 131), they argue that SRM is a political technology "in the sense of being unfavourable to certain patterns of social relations and favourable to others" (Szerszynski et al. 2013, 2811). Most importantly, Szerszynski et al. assert that CE deployment would "necessitate autocratic governance" (Szerszynski et al. 2013, 2812) and thus, act against the democratic organization of society. They base this on the assumption that SRM would "generate a closed and restricted set of knowledge networks, highly dependent on top-down expertise and with little space for dissident science" (Szerszynski et al. 2013, 2812) and that, "[i]n the face of a future 'crisis', it would be difficult to imagine how public responses could be directly involved in developing solutions" (Szerszynski et al. 2013, 2812).

The issue of how geoengineering will influence democracy and participatory decision making is brought up by Thomas Schelling as early as 1996:

> "The first thing to say about […] geoengineering compared with CO_2 abatement is that probably it totally transforms the greenhouse issue from an exceedingly complicated regulatory regime to a simple […] problem of international cost sharing." (Schelling 1996, 305)

Accordingly, the logic of decision-making and implementation of geoengineering is very different from that of mitigation. While Schelling considers geoengineering programs to be "not at all dependent on universal participation." (Schelling 1996, 305) In contrast to this, he states that "CO_2 abatement has to be very decentralized, very participatory and very regulatory." (Schelling 1996, 306) Hamilton argues in a similar vein when he maintains that climate engineering technologies are prone to support the current distribution of economic and political power:

> “Whereas mitigation policies like carbon taxes and emissions trading activate resistance from ‘system-justifying attitudes’, those same attitudes are likely to trigger support for geoengineering solutions because they are consistent with ideas of control over the environment and the personal liberties associated with free market capitalism.”(Hamilton 2013a, 91)

Accordingly, geoengineering is popular with conservative forces in the US and elsewhere, as Hamilton points out. Another version of this frame is brought up by Holly Jean Buck: “A critical reading views geoengineering as a class project that is designed to keep the climate system stable enough for existing production systems to continue operating” and to “extend the shelf life of fossil-fuel driven socio-ecological systems” (Buck 2012, 253). She finds that “it may be of benefit to fossil-fuel capitalism” (Buck 2012, 256), pointing out, however, that she does not find support for the idea that geoengineering is a capitalist-driven project. While the danger of loss of democratic and participatory mechanisms because of the introduction of CE technologies is touched upon, a systematic and empirical analysis of this danger has not yet been conducted.

Another framing of geoengineering as a driver of social dynamics is commonly discussed in the literature as either the ‘moral hazard’ or the ‘risk compensation’ problem. Both of these concepts describe the common concern that the increasing investment of effort into geoengineering might have detrimental effects on the effort undertaken to further mitigation and adaptation measures (see, for example, Bunzl 2009, 2; Shepherd et al. 2009, 37; Corner and Pidgeon 2010, 30; Heyen 2012, 43; Burns 2013, 209; Michaelson 2013, 100; Corner and Pidgeon 2014, 2; Rayner 2014, 6; Reynolds 2014a, 2). The first originates from “behavioral economics of insurance”, while the second is taken from “behavioral psychology of risk and safety” (Reynolds 2014a, 3). Moral hazard is understood as the “socially inefficient increase in risk-taking by one party once another party absorbs some of the potential negative consequences of the first party’s actions” (Reynolds 2014a, 3). A popular example is the assumed increase in reckless behavior in people who have health insurance. Risk compensation “is an increase or decrease in risk-taking once an individual perceives that risk to be lower or higher, respectively.” (Reynolds 2014a, 4) A common example is that of the increase of reckless driving since the introduction of seatbelts. While the moral hazard framing is more common in the literature, the risk compensation framing is understood to be a more precise fit for the problem at hand (Lin 2013a, 688-689; Reynolds 2014a, 3) In some studies, the two terms are used interchangeably (see, for example, Amelung 2012, 41).

Meteorologist Alan Robock draws up a list of “20 reasons why geoengineering might be a bad idea” as early as 2008 (Robock 2008, 15ff.; Robock, Marquardt, Kravitz et al. 2009, 2), in which he mentions the problem of moral hazard. The framing has been criticized from many sides, however. The BMBF report points out the weakness of its empirical basis for the case of climate engineering:

> "While the *moral hazard* phenomenon can be statistically proven in the case of other technological innovations, for example for the introduction of safety belts in cars, in the context of Climate Engineering, there is no empirical material which supports the *moral hazard* argument."[9] (Rickels et al. 2011, 86)

The authors of the Royal Society report agree that "there is little empirical evidence to support or refute the moral hazard argument in relation to geoengineering" (Shepherd et al. 2009, 39). The authors even turn the argument around, suggesting that "it is possible that geoengineering could galvanize people into demanding more effective mitigation action." (Shepherd et al. 2009, 39) Ben Hale's criticism has a different take when he concludes that moral hazard arguments fail: "they fail not because they are wrong or incorrect but because they are far too complicated and multilayered to do the work that they are assumed to do. They are […] both ambiguous and vague." (Hale 2012, 115) Martin Bunzl criticizes the claim on the basis of its political probability: accordingly, it seems "far-fetched since, at least among policy makers, nobody believes that geoengineering offers anything but a relatively short stopgap to buy time for other action." (Bunzl 2009, 2) Michaelson argues that "blaming geoengineering for complacency is like blaming a heart surgeon for saving the life of someone who does not exercise and who eats too much." (Michaelson 2013, 101) Thilo Wiertz considers that a different understanding of the moral hazard frame might be of use: "That a 'moral hazard' arises not from the technologies and their interaction with individuals, but from the power relations and regulatory logics characteristic to the international climate regime, is a concern that has remained absent from serious social scientific consideration so far." (Wiertz 2012, 52) Similarly, in opposition to the criticism that the moral hazard argument encountered, Albert Lin finds that is „likely that geoengineering efforts will undermine mainstream strategies to combat climate change and suggests potential measures for ameliorating this moral hazard" (Lin 2013a, 673), based on theoretical as well as empirical considerations. While all preceding texts analyze the empirical validity of the moral hazard argument, Morrow asks: "Why would it be a bad thing if climate engineering obstructed mitigation?" (Morrow 2014a, 1) Accordingly, he does not look for empirical evidence for or against the argument, but rather questions its characteristic as a problem.

[9] Translated by the author; original: „Während das *moral-hazard*-Phänomen bei anderen technischen Neuerungen, wie zum Beispiel dem Einführen von Sicherheitsgurten in Autos, statistisch belegt werden kann, gibt es im Kontext von Climate Engineering kein empirisches Material, das die *moral-hazard*-These unterstützt." (Rickels et al. 2011, 86)

4.3 Reference to international conflict: CE as a driver of transboundary conflict

One major political implication of CE as a way to deal with climate change problems is based at the international level: CE is analyzed as a potential source or a driver of transboundary conflicts. One major contribution to this analysis stems from a group of political scientists around Michael Brzoska and Jürgen Scheffran, who originally analyze the effect of climate change on issues like conflict, peace and security (see, for example, Scheffran, Brzoska, Kominek et al. 2012). The researchers approach climate engineering from a systematic perspective and argue that CE deployment can have effects on the global, regional, national, and local scale, which can lead to the development of new conflicts or the exacerbation of existing ones (see Brzoska, Link and Neuneck 2012, 191). Additionally, CE "could […] add new dimensions to conflict, particularly if their impacts are highly uncertain, quick, strong and heterogeneous, where the severity can vary regionally." (Maas and Scheffran 2012, 193) The authors also point to a thin silver lining, however, as "CE may possibly reduce climate-related conflicts" (Maas and Scheffran 2012, 193). At a conference in Hamburg in 2011, the implications of climate engineering for peace and security where the central issue, and the summary of this conference points to the problems of the "unequal distribution of the effects", "additional unintended side effects" and the thin line between hostile and peaceful applications of CE measures as potential sources of conflict (Link, Brzoska, Maas et al. 2013, 15). Paul Nightingale and Rose Cairns move beyond a "standard Geo-political framing of security" (Nightingale and Cairns 2014, 3) and analyze indirect security implications of SRM, for example the attribution of blame for extreme weather events. They find that "from a security perspective SRM is costly, ungovernable, and raises security concerns of a sufficient magnitude to make it a non-viable policy option." (Nightingale and Cairns 2014, 3)

The question whether geoengineering will lead to more or less international security is posed by a number of papers. Cairns approaches it from a critical perspective and analyses the security implications of climate change and of geoengineering (Cairns 2014). Several authors focus on one particular aspect of the security question: the danger of unilateral action. The observation that CE technologies, other than mitigation, do not need concerted action from a number of states to be effective, and the subsequent concern that they might be developed or even deployed by a single country unilaterally, are raised in the literature early on (see, for example, Victor 2008, 324; Barrett 2009, 15; Shepherd et al. 2009, 40; Rickels et al. 2011, 69; Brzoska et al. 2012, 191). Barrett, for example, points to the danger of unilateral action connected with the development of CE technologies: "An important aspect of geoengineering is that it can be undertaken by a single country, or by a coalition of the willing." (Barrett 2009, 15) Empirically, many countries would have a good number of reasons to do so (see, for example, Barrett 2009, 15; Edney and Symons 2014, 15) and some of them, like China or India, command the scientific and political capabilities necessary (ibid.). Joshua Horton, however, challenges the argument of unilateralism and argues "that this fear […] is largely misplaced, grounded more in unexamined policy assumptions than in reasoned analysis of the strategic situation faced by states." (Horton 2013, 168) To support this claim, he assumes that "[g]eoengineering, governed by a multilateral logic, represents a benign problem structure with relatively few obstacles to cooperation. Indeed, geoengineering features structural supports that make cooperation advantageous if not necessary." (Horton 2013, 176) Weng Weili and Chen Ying examine the assumption that China "would unilaterally resort to this 'Plan B'", finding that "these arguments on China's position and strategies towards geoengineering can be fallible" (Weili and Ying 2014, 1).

4.4 Reference to political interests: CE as a political arena

Yet another political set of frames presents climate engineering as an arena of political interactions: "In this light, Climate Engineering governance presents itself as an arena of conflicting voices, characterized by different logics competing over the meaning of the technologies." (Wiertz 2012, 53) Entities with vested interests in the issue of climate engineering can be, for example, states in the international system or individual actors in a society. For the international system, Schellnhuber ascertains that "[c]ertain countries like Russia might actually welcome some warming of their territories. […] [T]he supposed beneficiaries of climate change might deliberately increase their greenhouse gas emissions for overcompensating SRM, and so on." (Schellnhuber 2011, 20278) Juan Moreno-Curz analyzes strategic effects of geoengineering in the international system, finding that "geoengineering does not necessarily increase the free-riding effect on mitigation" (Moreno-Cruz 2011, 20). Similarly, Katherine Ricke, Moreno-Cruz and Ken Caldeira analyze the "strategic behavior of players in a global thermostat game" and ascertain that it "is best represented by a public goods club" (Ricke, Moreno-Cruz and Caldeira 2013, 7). They add that "[t]here is incentive to exclude willing allies in order to maximize the climate benefit among the winning coalition members" (Ricke et al. 2013, 7).

But not only between states, also inside of societies, CE is viewed in the literature as an arena in which conflicting or converging interests meet. Inside of politics, Simon

Nicholson and Michael Thompson find that “climate engineering subverts traditional left-right politics” (Nicholson and Thompson 2015, 1): While traditionally, Republications reject the notion of anthropogenic climate change, the option of geoengineering finds approval (see also Hamilton 2013a, 90). Bjornar Egede-Nissen highlights the role of scientists as entities with vested interests when analyzing “scientists as gatekeepers of knowledge, aspects of scientific parochialism, and the involvement of scientists in private geoengineering endeavours” (Egede-Nissen 2010, 1). Both Christopher Belter and Dian Seidel (2013) and Paul Oldham and colleagues (Oldham, Szerszynski, Stilgoe et al. 2014) analyze the publication behavior of scientists when it comes to geoengineering, using the method of bibliometric analysis. While the former give a general overview over the distribution article types, nations of origin, disciplines and connections between the issues discussed (Belter and Seidel 2013, 417), the latter attempt to “contribute to democratic deliberation on the governance of climate engineering in general […] by seeking to make visible emerging patterns and structure in scientific research and patent activity.” (Oldham et al. 2014, 17)

Different social entities in this arena can also be closely intertwined with each other, a phenomenon which is critically examined in a number of publications. Sikka finds that “it becomes blatantly clear 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 2012a, 173) Eli Kintisch identifies a ‘geoclique’ comprised of some participants at a workshop on climate science in Harvard in 2007 around the two scientists David Keith and Ken Caldeira, among them David Battisti, Lowell Wood, Dan Schrag, Chris Field, and Bob Frosch. “This was the geoclique, as I called them, led informally by Caldeira and Keith. Some were topflight scientists, such as Caldeira; some were knowledgeable retirees or what seemed to be hobbyists.” (Kintisch 2010, 8) Hamilton asserts: “Although still in its early days, the constituency for geoengineering is now developing around a network of individuals with personal, institutional and financial links.” (Hamilton 2013a, 72) He points out the interest in geoengineering technologies shown by a number of US-billionaires such as Bill Gates and Richard Branson and their connections to scientists involved in CE research as well as the relevance of economic interests in the Arctic or in upcoming patents on CE technologies: “It is clear, even at this early stage, that burgeoning commercial engagement in geoengineering is creating a constituency with an interest in more research and, eventually, deployment.” (Hamilton 2013a, 80) He warns: “Once political, corporate, and military players become involved, geoengineering experts will lose control of how the technology is used.” (Hamilton

2014, 21) Similarly, with an eye also on military funding of geoscience and other, more subtle issues of interconnectedness between science, the military and the government during the Cold War (see Fleming 2010, 167), Fleming warns that "[c]ontemporary engineers err if they ignore this history" (Fleming 2013, 4). The case of nuclear weapons development is considered particularly telling by some authors as a "disproportionate number of scientists currently working on geoengineering have either worked at, or collaborated with, the Lawrence Livermore National Laboratory" (Hamilton 2014, 22), which was a centerpiece of US nuclear research during the Cold War.

4.5. Reference to science and technology studies: CE as a social technology

Considering or framing CE measures as a set of technologies seems to be a pretty straight-forward approach at first glance: They are, after all, a set of tools designed to serve a certain purpose. However, the terms used to describe CE measures in that way are fraught with a number of connotations and implications which are, in turn, the domain of science and technology studies. Hamilton draws attention to these implications when analyzing the "ethical foundations of climate engineering" (Hamilton 2013b, 39) and warns that understanding CE merely as a technology is an expression of what he terms "technological thinking":

> "According to this view technology transforms potentially useful things into useful things without asking about the origins of the world as a collection of potentially useful things. […] As such, modern technology reveals something essential to the nature of modern humans – the determination to shape the world around us to suit our desires, desires that have no limit." (Hamilton 2013b, 56)

This means that, when CE is understood purely in terms of technology, this understanding is based on the hubristic notion that everything in the world is there only for the use of and transformation through human inventiveness. Very early in the debate, Jeffrey Kiehl notes that "we would be taking on the ultimate state of hubris to believe we can control Earth" (Kiehl 2006, 227), thus infusing the issue of human hubris into the discussion on technology in general, and on CE in particular.

The idea of the 'technofix' is an expression of the belief that technology can help fix any problem. It is not specific to the CE discourse, but surfaces here regularly (see, for example, Corner and Pidgeon 2010, 30; Borgmann 2012, 189; Scott 2012, 151; Hulme 2014, 1). As Dane Scott elaborates, those notions are comprised in the philosophy of 'technological progressivism'. This view on the relationship between humans and technology maintains that "the consistent application of science and technology is humanity's greatest hope for improving human life" (Scott 2013, 2).[10] 'Big science' describes the idea that science has the "power to solve social problems" (Scott 2013, 2) through technofixes which are capable of reducing "the seemingly insurmountable complexity of social and political problems" (Scott 2013, 2) to technological problems which are more easily defined and provide decision makers with more options.[11] Technofixes, however, also come with their own set of problems, which need to be addressed if CE measures are considered technologies. For example, technofixes are criticized for not getting at the root cause of the problem: "The moral intuition behind this criticism is that in using technological fixes we are avoiding important engagements in the word that *ought* to be required to solve a problem." (Scott 2013, 7) Albert Borgmann's 'device paradigm' (Borgmann 1987, 40ff.) captures this notion of a tradeoff between the unburdening capacity of technologies and the consequential loss of engagements with the natural and social world. An example is the introduction of the telephone: It unburdens people from having to talk to others personally very time they want to get in touch, but it also in turn reduces direct human contact. Scott uses this paradigm to pose new questions about CE technologies: "All things considered, does this particular proposal take away burdens we ought not to be rid of?" (Scott 2013, 8) Burdens of this kind are, for example, public deliberation of social and political problems.

Seth Baum analyses the "downside dilemma for emerging technologies" (Baum 2014, 2), which consists of two options: "use the technology, and risk the downside of catastrophic failure, or do not use the technology, and suffer through life without it." (Baum 2014, 1) Sikka goes a step further and looks for "ways in which technology can be made into a public issue" (Sikka 2012b, 109), thus pursuing the goal of actively increasing public deliberation instead of letting it be reduced. Applying a critical theory of technology, she maintains that "[g]eoengineering can […] be understood as *the* penultimate human technology whose objective is to manipulate the natural world without any consideration of moral or ethical norms." (Sikka 2012b, 112) Similarly, Szerszynski critically analyzes the framing of climate engineering in technical terms and comes to the conclusion that, even compared with the irresponsible action of questioning climate change, "it is the dominant technological framing of climate change that ultimately constitutes a more radical evasion of responsibility." (Szerszynski 2010, 22) He traces the history of the current "technological condition" of

[10] Other philosophies view technology as tools to be used at the discretion of their users (instrumentalist view/ technological pragmatism) or "constituted by a destructive essence" (Sikka 2012b, 112) (technological pessimism)

[11] The terms ‚Big Science' and ‚technofix' were coined by Alvin Weinberg (see, for example, Weinberg 1967).

humanity to “show how that kind of analysis can be applied to geoengineering, to reveal how it is an aspiration that has roots that are a lot longer than the modern period” (Szerszynski 2014, 3).

Another important notion in the context of discussing CE measures as technologies is that of the ‘Anthropocene’ (Crutzen and Stoermer 2000, 17): It suggests

> “(i) that the Earth is now moving out of its current geological epoch, called the Holocene and (ii) that human activity is largely responsible for this exit from the Holocene, that is, that humankind has become a global geological force in its own right.” (Steffen, Grinevald, Crutzen et al. 2011, 843)

Geoengineering is considered as an indicator that humanity stands at the doorstep of the Anthropocene, a new epoch in Earth history, or that it has already entered into it (see, for example, Steffen et al. 2011, 858; Galaz 2012, 25; Schäfer, Stelzer, Maas et al. 2014, 239) and for the way in which society might deal with “the complex set of questions that emerges with the ability to fundamentally intervene in natural processes on global scale […], and how this interacts with social and political order.” (Schäfer et al. 2014, 243) The notion is strongly criticized, for example for being a “fetishism” (Cunha 2015, 65) originating from capitalist ideology. Simon Dalby puts the notion into the context of geopolitics, arguing that “[w]hile geopolitics used to be about the context of global politics, now in the Anthropocene, it has become a matter of remaking that context rather than taking it as a given.” (Dalby 2015, 190)

One major criticism against CE measures when presented as technologies is that of uncertainty: There are aspects, consequences and implications of CE that are not known, and some of these cannot be known without the actual deployment of the technologies (see Shepherd et al. 2009, 37; Keith 2013, 72; Michaelson 2013, 101). This uncertainty or risk is, also, not specific to CE, but crops up in modern-day society at the interstices between science and politics (Beck 1998, 10). Dorothee Amelung and colleagues point out that “CE technologies can be viewed as uncertainty about involved agents, potential unintended consequences and potential losses” (Amelung et al. 2012, 5). Aiming at understanding the way in which uncertainty influences the way that CE is dealt with, Bidisha Banerjee applies Sheila Jasanoff’s ‘technologies of humility’ framework (Jasanoff 2007, 33) to geoenengineering technologies in her analysis of CE governance proposals in order to “accommodate the partiality of scientific knowledge” (Jasanoff 2007, 33). Uncertainty can be considered either a solely scientific problem – for example due to errors of measurement or to modelling without regard for relevant aspects (Banerjee 2011, 23) – or as a problem with psychological and political characteristics – for example “errors of the political problemsolver in his interaction with the situational demands of complex problems" (Amelung and Funke 2013, 32).

The possible consequences of talking about CE measures as technologies are analyzed in a general manner by Heyward and Rayner. They "highlight[…] the technocratic overtones of the previous climate change and environmental discourses that facilitated the advent of geoengineering research as a serious policy option" (Heyward and Rayner 2013b, 3).

4.6 Reference to ethical implications: CE as an issue of moral consideration

A number of concerns are raised when the climate engineering option is viewed as an issue of ethics. The most prolific authors about CE as an ethical issue are Clive Hamilton and Stephen Gardiner, but ethical implications of the matter are considered in other and also in more general publications as well. Hamilton states: "At its core, climate engineering is a moral question." (Hamilton 2013a, 158) The authors of the Royal Society Report agree: "Overall it is clear that ethical considerations are central to decision-making in this field." (Shepherd et al. 2009, 39) In a number of publications, the moral hazard/ risk compensation argument and the slippery slope argument against CE development and the arguments of buying time and climate emergency for CE measures are considered as ethical implications. Here, these have been classified as social implications, because they are aspects of CE as a driver of social change. Ethical implications of CE are here understood as those aspects which involve arguments about right and wrong. Examples for analyses of individual ethical doctrines and their relevance for CE are the study of the doctrines of doing and allowing and of double effect (Morrow 2014b) as well as the principles of respect, beneficence and justice, the minimization principle (Morrow et al. 2009) or the analysis of implications of SRM for intergenerational equity (Burns 2013) and distributive justice (Wong 2014). Two important arguments with a more global perspective are the desperation argument for CE and the creative myopia or moral failure argument against it. The discussion of the desperation argument in particular lends itself to a critical examination of the framing of CE as an ethical issue.

The desperation argument is the ethical twin of the social argument of climate emergency. Gardiner summarizes its structure somewhat casually: "'What if, in the face of catastrophic impacts, the most vulnerable countries initiate geoengineering themselves, or beg the richer, more technically sophisticated countries to do it? Wouldn't geoengineering then be ethically permissible? […]'" (Gardiner 2013a, 28) Different interpretations of this argument –

for example the consent interpretation, which claims that CE is justified when the vulnerable indicate their consent to CE by directly or indirectly deploying it, or the self-defense interpretation, which claims that CE is justified because deployment through the vulnerable is a moment of self-defense which they have a right to – are discussed in the literature (Corner and Pidgeon 2010, 29; Preston 2012a, 4; Whyte 2012, 65; Gardiner 2013a, 28+29; Gardiner 2013b, 15; Goeschl, Heyen and Moreno-Cruz 2013, 85).

Hamilton maintains that "[c]limate engineering might lend itself to moral corruption." (Hamilton 2013a, 162) He calls to looking at the bigger picture of climate policy and finds that "if climate engineering is inferior to cutting emissions […], then merely by choosing to engineer the climate instead of cutting emissions we succumb to moral failure." (Hamilton 2013a, 162) Similarly, Gardiner finds that climate change constitutes a "perfect moral storm" (Gardiner 2006) and that, consequently, CE itself is unethical because it allows for the 'passing of the buck' by those originally responsible for climate change. A perfect moral storm is defined as "the unusual intersection of a number of serious, and mutually reinforcing, problems, which […] are all obstacles to our ability to behave ethically." (Gardiner 2011, 7) The problems in the case of climate engineering are of global, intergenerational and theoretical nature. Practically, the moral storm of climate change works like this:

> "At the heart of the matter is the fact that those most responsible for past and current emissions, the relatively affluent, […] believe that they benefit from high carbon emissions, but most of the costs of such emissions […] are projected to fall on future generations, non-human nature, and especially the global poor. As a result, the current generation of the affluent face strong temptations to pass the buck for their behavior on to others who are extremely vulnerable to them." (Gardiner 2013a, 30)

These temptations are given in to when CE is deployed, as it allows the responsible actors to pass on paying the cost on climate change. Gardiner develops this argument further with the notion of 'creative myopia':

> "This [creative myopia] arises when an agent invokes a set of strong moral reasons to justify a given course of action, but his course of action is supported by these reasons only because the agent has ruled out a number of alternative courses of action more strongly supported by the same reasons, and where this is due to motives she has that are less important, and are condemned by other reasons." (Gardiner 2013b, 19)

This means that the same arguments (e.g. the emergency argument) which are brought forth in support of CE could be used to support stronger mitigation action, which has, in turn, been excluded from the debate for reasons such as its influence on economic growth or its political feasibility. Gardiner calls this a form of 'moral schizophrenia', a "split between one's motives and one's reasons" (Gardiner 2013b, 19): Accordingly, geoengineering "requires us to emphasize and endorse strong ethical concerns that we are otherwise unwilling to act on, and which would, if earnestly and coherently embraced, lead us to approach both climate policy in general and geoengineering in particular in very different ways." (Gardiner 2013b, 12)

4.7 Reference to economic implications: CE as an issue of cost-benefit-analysis

Economic framings of CE are, to the knowledge of the author, not yet an issue of critical analysis. Analysis of economic factors of the issue, however, makes up a small, but growing part of social science literature on CE. Cost-benefit-analysis is discussed or applied to one or more technologies in a number of publications (see, for example, Barrett 2008; Schneider 2008; Shepherd et al. 2009, 44ff.; Greene 2010; Greene, Monger and Huntley 2010; Fernow 2012; Klepper 2012; McClellan, Keith and Apt 2012; Doda 2014). The direct costs of some geoengineering strategies such as sulfate aerosol dispersal in the Stratosphere or ocean iron fertilization are considered comparatively low by most authors (see, for example, Bickel 2010, 25; Bickel and Agrawal 2012, 993; McClellan et al. 2012, 6; Güssow et al. 2013, 251; Lane 2013, 116; Moreno-Cruz and Keith 2013, 443) – or, as Barrett puts it, "incredible" (Barrett 2008, 49). However, there exists a wide range of opinions and calculations, and accordingly, some substantial disagreement, concerning indirect and hidden costs of these technologies (see, for example, Goes, Tuana and Keller 2011, 720; Bickel and Agrawal 2012, 993; Fernow 2012, 17; Klepper 2012, 211; Doda 2014, 19). Additionally, the incapability of SRM measures to counter other climate change consequences such as ocean acidification or the build-up of greenhouse gases is pointed out (Moreno-Cruz and Smulders 2010, 25; McClellan et al. 2012, 7).

5. Concluding remarks

This review investigated which representations of CE are considered relevant in the social science literature. The author draws two conclusions. First: The dominant frame is that of climate engineering as (part of) a solution to the political problem of climate change. Differing opinions exist on whether it is a good or a viable option. On the basis of this frame, investigations are launched into more specific issues. Second: Below the level of that dominant frame, a number of frames of climate engineering and their implications are subject to analysis in the literature.

The review has also indicated the relevance that social sciences grant frames in the discourse on geoengineering in general (see, for example, Bowden 2010; Nerlich and Jaspal

2012; Sikka 2012a; Cairns 2013; Markusson 2013; Porter and Hulme 2013; Szerszynski and Galarraga 2013; Anshelm and Hansson 2014a; Anshelm and Hansson 2014b; Bellamy 2014b; Carr et al. 2014; Corner and Pidgeon 2014; Huttunen and Hildén 2014; Luokkanen et al. 2014; Uther 2014): Many authors stress how the ways in which geoengineering is talked about is important for the ways in which it might be dealt with in the future (see, for example, Fleming 2010, 182; Wainwright and Mann 2012, 5; Hamilton 2013a, 91; Heyward and Rayner 2013a; Szerszynski et al. 2013, 2809; Hulme 2014, 136; Markusson et al. 2014, 281). The framing of climate change in terms of a climate emergency, for example, could lead to the application of geoengineering technologies without democratic deliberation (Horton 2015). The issues of potential loss of democratic mechanisms are touched upon in the social sciences.

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