Climatic Change
DOI 10.1007/s10584-013-0763-y

Public engagement on solar radiation management and why it needs to happen now

Wylie A. Carr · Christopher J. Preston · Laurie Yung · Bronislaw Szerszynski · David W. Keith · Ashley M. Mercer

Received: 5 September 2012 / Accepted: 4 April 2013

Abstract There have been a number of calls for public engagement in geoengineering in recent years. However, there has been limited discussion of why the public should have a say or what the public can be expected to contribute to geoengineering discussions. We explore how public engagement can contribute to the research, development, and governance of one branch of geoengineering, solar radiation management (SRM), in three key ways: 1. by fulfilling ethical requirements for the inclusion of affected parties in democratic decision making processes; 2. by contributing to improved dialogue and trust between scientists and the public; and 3. by ensuring that decisions about SRM research and possible deployment are informed by a broad set of societal interests, values, and framings. Finally, we argue that, despite the nascent state of many SRM technologies, the time is right for the public to participate in engagement processes.

This article is part of a special issue on "Geoengineering Research and its Limitations" edited by Robert Wood, Stephen Gardiner, and Lauren Hartzell-Nichols.

W. A. Carr (✉) · L. Yung
Department of Society and Conservation, University of Montana, 32 Campus Drive, Missoula, MT 59812, USA
e-mail: wylie.carr@umontana.edu

C. J. Preston
Department of Philosophy, University of Montana, 32 Campus Drive, Missoula, MT 59812, USA

B. Szerszynski
Department of Sociology, Lancaster University, Bowland North, Lancaster LA1 1YT, UK

D. W. Keith
School of Engineering and Applied Sciences and Kennedy School, Harvard University, Pierce Hall, 29 Oxford Street, Cambridge, MA 02138, USA

A. M. Mercer
Institute for Sustainable Energy, Environment and Economy, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada

Published online: 15 May 2013

1 The context for public engagement in solar radiation management

Solar radiation management (SRM) has recently received increasing scientific, political, and public attention. SRM is a form of geoengineering that seeks to lessen the harmful impacts of climate change by altering the earth's albedo. Possible techniques include increasing the concentration of sulfuric acid droplets in the stratosphere or increasing marine cloud lifespan and albedo using salt water droplets (Royal Society 2009). While not a new idea (Keith 2000), attention to SRM increased dramatically with the publication of atmospheric chemist and Nobel Laureate Paul Crutzen's (2006) article "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" We focus here on SRM, as a subset of geoengineering technologies, because several SRM techniques currently are regarded as potentially inexpensive and technologically feasible, and could rapidly alter the entire climate system with global implications.

Since 2006, numerous scientific and policy reports have called for increasing research on SRM at both national and international levels. These reports have advocated increased funding for scientific and engineering research on SRM, recommended the coordination of interdisciplinary research to address the multifaceted ethical, legal, and social issues that SRM raises, and also advanced calls for public engagement. In fact, "public participation in geoengineering decision-making" is one of the five recommendations that make up the Oxford Principles, perhaps the most well-respected set of norms proposed to date for the governance of geoengineering research (Rayner et al. 2009). As Steve Rayner et al. point out in this volume, this principle encapsulates a "primary concern for legitimacy" of any future geoengineering activity (2013). Similar calls for engagement have featured in reports such as the Royal Society's (2009) *Geoengineering the Climate*: *Science*, *Governance and Uncertainty*, the House of Commons Science and Technology Committee's (2010) *The Regulation of Geoengineering*, the Bipartisan Policy Center's (2011) *Geoengineering*: *A National Strategic Plan for Research on the Potential Effectiveness*, *Feasibility*, *and Consequences of Climate Remediation Technologies*, and the Wilson Center's *Geoengineering for Decision Makers* (Olson 2011).

While these reports correctly identify a need for public input into SRM research and policy-making, they fail to adequately specify the purpose of public engagement and explain why it is necessary. Social scientists, on the other hand, have explored the justifications for the inclusion of the public in the early stages of technological research and development, and have begun to carry out preliminary public engagement exercises on SRM in the United Kingdom (UK) (e.g. Corner and Pidgeon 2010; Corner et al. 2012; Macnaghten and Szerszynski 2013). We wish to build upon this work by further exploring *why* public engagement must play a role in SRM, and *how* public engagement processes can contribute to SRM research and governance. More specifically, we hope to provide an accessible interdisciplinary argument, consisting of social, ethical, and technological justifications for engaging the public, to the broader community of climate scientists, policy-makers, and non-governmental organizations.

We define "public engagement" as participatory processes through which members of the public convey their views, concerns, and recommendations about emergent technologies and related decision-making, with the idea that the outcomes will inform both research and policy-making. Both advocates and critics of public engagement have sometimes seen it merely as a public relations strategy to convince the public to support a proposal that an organization wishes to press forward. Here we argue for public engagement as a legitimate, democratic dialogue about whether and how to advance a particular technology. Public engagement of this sort moves beyond viewing citizens as passive recipients of expert

opinions and recognizes the importance of actively involving citizens in technological design and policy making, and in shaping the goals and animating questions of public engagement exercises themselves (Wynne 2006). Such engagement informs and lends legitimacy to research, the governance of research, and policy decisions regarding a technology's regulation and/or possible deployment. The importance of public participation in the research, development, and regulation of emergent technologies is now widely recognized by both governments and scientific bodies (European Commission 2002; House of Lords 2000; Leshner 2003), and has been widely discussed and implemented in the case of nanotechnology in recent years (Delgado et al. 2011; Kearnes et al. 2006; Macnaghten et al. 2005; Royal Society 2004).

The latest report by the Solar Radiation Management Governance Initiative (SRMGI 2013) briefly mentions three rationales or motivations for engaging the public on emerging technological and scientific issues.[1] We utilize these three justifications as a starting point for examining the purpose and utility of public engagement processes in relation to SRM. The first is a normative or ethical rationale which views participation as necessary based on principles of equity and justice—people simply deserve to be informed about and have a say in a technology that has the potential to affect their lives. The second is an instrumental motivation frequently associated with bringing about particular outcomes, for instance minimizing adverse public responses to an emergent technology, promoting public awareness, or fostering trust in the scientists who design particular technologies and the institutions that regulate them (Royal Society 2004: 63). The third rationale for public participation is substantive, motivated by the desire to actually improve the quality of decisions involving SRM technologies via the incorporation of broader knowledge and active deliberation between publics, experts, and policy makers. Substantive motivations encourage the incorporation of diverse perspectives into research and development processes in order to improve both the relevance and effectiveness of resulting products, be they technologies themselves or regulatory policies surrounding implementation. The remainder of this article explains why all three rationales for public participation are relevant to SRM, provides concrete reasons why public participation is necessary from ethical, political, and technological perspectives, and explains why *now* is an appropriate time to begin engaging diverse publics in meaningful dialogue about SRM research and policy.

1.1 Normative justifications

Scientists involved in SRM research have been quick to acknowledge that the ethics of SRM are challenging. Many forms of SRM are designed specifically to impact the *global* climate. Modeling studies suggest that SRM techniques will likely have uneven impacts on regional and local climates (Moreno-Cruz et al. 2012; Ricke et al. 2010; Robock et al. 2008). As with unintended anthropogenic climate change (IPCC 2007), there will be winners and losers with SRM. Because the world's poor are most vulnerable to climate change they might be expected to benefit most from SRM, particularly if the technology mitigates expected losses in crop productivity (Pongratz et al. 2012). However the uneven effects of SRM mean that some people living at the subsistence level may be worse off if such technologies are implemented (Moreno-Cruz et al. 2012; Robock et al. 2008).

The possibility of uneven benefits and burdens raises difficult ethical issues involving consent and participation (Preston 2012). The deployment of SRM could be intrinsically

[1] Although attributed to Stirling (2005) in the SRMGI (2013) report, these rationales for public engagement date back to Fiorino (1990).

unpredictable in its effects, both on climatic processes and political systems (Hulme 2010; Macnaghten and Szerszynski 2013). Further, the very promise of SRM technologies could further weaken progress toward the reduction of carbon emissions. These issues by their very nature *demand* public engagement. To avoid compounding the existing injustices of climate change (Shue 1992), diverse populations whose lives, livelihoods, and societies could be significantly impacted by SRM should have the opportunity to be informed about the various technologies being proposed and how they might be affected. The requirement to be informed is essentially "an acknowledgement of one's moral status" (Rayner et al. 2013) (i.e. of that fact that one counts morally). Additionally, these same populations should be afforded the opportunity to deliberate about, consent to, and agree to bear any possible harms of both field testing and possible deployment.

How the public conceives of notions such as 'participation' and 'consent' will influence how engagement processes are viewed and the ways in which they are implemented in practice (Rayner et al. 2013). In the case of SRM, the task of enabling meaningful public engagement that contributes to legitimate governance processes is complicated by the fact that it must be international in scope. Additionally, it must consider highly technical questions about a nascent technology that could be designed or used with a variety of intentions that will be difficult to pin down or regulate (Corner et al. 2012; Stilgoe 2011). While cognizant of these challenges, we suggest there is a moral imperative that diverse publics begin to contribute in meaningful ways—and soon—to discussions about whether and how any SRM testing and deployment should take place.

Public engagement is arguably even more necessary since the traditional institutions and practices of representative democracy may be inadequate to address the global implications of SRM technologies. The scale and scope of SRM proposals necessitates public engagement processes that seek out diverse views and encourage dialogue about public concerns and the assumptions that shape research priorities (SRMGI 2013; Wilsdon and Willis 2004). This needs to take place not only in the United Kingdom, where, as Corner et al. (2012) highlight, engagement processes on SRM are already taking place, but also in regions of the world where SRM is just beginning to enter the scientific and political lexicon. Engagement methods such as stakeholder groups, citizens' juries, consensus conferences, and scenario workshops, among others, can be designed in culturally sensitive ways to ensure meaningful public participation at local, national, and even global levels (Rusike 2005).

1.2 Instrumental justifications

As the term itself indicates, instrumental rationales have tended to view public engagement as a tool for advancing particular goals. Instrumental public engagements have often taken the form of assessing public understanding and opinions about a given technology in order to shape strategic communications designed to generate public support or to prevent adverse responses (Stirling 2005). More manipulative forms of 'engagement' are already, and will continue to be, utilized by groups attempting to sway the debate on SRM in particular directions, by presenting information that is selective and framed in ways that are likely to lead to predetermined conclusions rather than genuinely open dialog and debate. However, instrumental engagements need not follow this trajectory. In fact, more recently, instrumental arguments for public engagement have tended to focus more on the positive indirect effects of greater openness and transparency about science and technology, including increased trust in public institutions, to the extent that those institutions are genuinely willing to open up their assumptions and self-conceptions to challenge and reformulation (Wynne 2006).

In the case of SRM, research into public perceptions can play a different but no less important instrumental role. While public perception methodologies such as survey research can reproduce the assumptions of researchers, and do not foster the back and forth dialogue between experts and publics characterized by effective public engagement methodologies, carefully crafted surveys and thoughtful assessment of public perceptions can play a critical role in promoting public awareness and debate about SRM. While often not explicitly aimed at integrating public concerns into policy-making or technological design, public perceptions work can make attentive scientists, engineers, and policy-makers aware of the social dimensions involved in the introduction of new technologies. The nascent nature of SRM research means that, while public awareness may be on the rise (Mercer et al. 2011) and media and political frames are beginning to take shape (Scott 2012), the majority of the global population is not familiar with the topic. As such, research aimed at understanding public perceptions of SRM and tracking changes in those perceptions over time can enhance our understanding of how to best facilitate dialogue between experts, policy makers, and the public about SRM and its attendant issues. For these reasons, research methods aimed at gauging public perceptions of SRM, such as mail and online surveys, telephone polls, and focus groups, while not constituting engagement in and of themselves, can provide valuable information that can inform more participatory processes in the future.

It is important to note that SRM is a contentious issue and it would be a mistake to try to reduce the discourse around it to a bland consensus that conceals genuine differences in interests, values, and framings. It would be even more problematic for public engagements to be utilized to maximize the power of a public relations campaign or to manipulate public opinion. As the Royal Society (2009: 42) has stated, "the full potential of any public engagement will not be realized if it is motivated primarily by a desire by advocates to secure public consent to geoengineering". Rather, we need to know how different publics approach SRM, what they are concerned about, and how the stakes involved in SRM research and deployment decisions can be better articulated and debated. Crucially, this might involve changing the framings and assumptions of scientists, engineers, and policy makers, as much as those of the public.

1.3 Substantive justifications

Common misperceptions of the role of public engagement build on assumptions that technologies spring forth fully formed from the sciences, and that the role of the public is simply to shape decisions about their use, including the possibility of their prohibition. This framing deeply misconceives the task at hand in researching and developing SRM technologies and the appropriate role of public involvement. Rather than *science*, the development of SRM tools may be more usefully seen as *engineering*—the practical application of science to satisfy human needs or solve human problems. Science does not discover tools to manage climate risks by manipulating solar radiation any more than science discovers the iPod. The development of both is an engineering process that starts with a particular problem-definition, and—ideally—proceeds on the basis that the resulting technology will have to function under real-world conditions, and must thus take account of the likely interaction of users with the technology and the possibility for its misuse.

However, scientific and engineering communities involved in the development of SRM technologies will inevitably make assumptions—implicitly or explicitly—about the following: the objectives of the technologies; the criteria that should be used to assess them and how they should be weighed; the kinds of knowledge appropriate to draw upon for research; and the meaning and significance of public concerns (Galarraga and Szerszynski,

forthcoming). Thus, one substantive justification for public engagement is to open up these assumptions (Stirling 2005), and to try to ensure that research considers the broadest possible set of framings of SRM and related issues. This approach is more likely to produce socially robust research outcomes.

To do so, public engagement processes could directly deliberate plausible objectives for SRM technologies, for example, (1) keeping the climate as near as possible to pre-industrial conditions, (2) maximizing agricultural productivity, or (3) managing the consequences of low-probability high-impact 'climate catastrophes'. They could also interrogate how technical choices during the development of SRM would shape costs, the extent to which technological control would be dispersed or centralized, and how vulnerable SRM might be to disruption by societal changes like economic recessions or wars. Public engagement could also be used to challenge embedded problem-definitions to which the proposed technologies are presented as a solution (Stirling 2005), to question the plausibility of using 'technical fixes' for complex problems (Sarewitz and Nelson 2008), and to examine how well the assumptions made by technical and governance communities about SRM are likely to stand up under real-world conditions (Macnaghten and Szerszynski 2013). Without such public input the technical community developing SRM will tend to fall back on the implicit assumptions of a relatively homogeneous community (Kitcher 2001; Longino 1990; Wilsdon and Willis 2004) .

Public engagement can help to democratically weigh and refine the objectives that drive SRM research, and help prevent a scenario in which the unstated assumptions of a community of developers ultimately impact the global population. Such engagement processes can also create the space for ideological discussions about the place and role of emergent technologies in our lives, and about the nature of the world that SRM deployment might bring about. Opposition to new technologies is often based on reasoned distrust of those who will be in control of new technologies and how they will use them, and on an assessment of the kind of social relations that the technologies seem to imply (Grove-White et al. 2000). If engagement processes facilitate recognition and genuine understanding of divergent views on SRM by scientists and engineers, such processes have the potential to incorporate a broad diversity of concerns into technological and policy decisions from the outset. SRM would give certain groups an unprecedented amount of leverage over our planet. Public engagement can help society to decide whether SRM *should* go ahead, but also help define the proper goals and boundaries of that leverage if it *does*. Such engagement needs to be characterized by an iterative dialogue that includes mutual learning and ultimately mutual design of SRM research and technology.

2 The time is now

Are everyday citizens around the world ready and able to discuss SRM in a meaningful way? We think the answer is yes. The potential for diverse publics to meaningfully engage in early dialogue about emergent technologies has been amply demonstrated over the past decade. In cases ranging from genetically modified foods to nanotechnology, researchers have found that citizens are able to engage in thoughtful discussion about nascent and complex technologies even when public awareness is low (Kearnes et al. 2006; Stilgoe and Wilsdon 2007). In fact, public engagement can be more effective when initiated while technologies and the public discourses surrounding them are still taking shape. Participants in public engagement exercises do not need to have substantial knowledge of the technology of interest beforehand. They can come to well-reasoned judgments about a

technology through a combination of basic information conveyed during the engagement process, their own 'lay' knowledge about nature and technology, and their commonsense knowledge of the social world (Marris et al. 2001). In fact, several recent public engagement efforts in the UK have demonstrated that citizens are able to critically assess social, ethical, and technical aspects of SRM research when provided with relatively minimal information (Corner et al. 2012; Macnaghten and Szerszynski 2013). These engagement efforts and a survey in North America and the UK (Mercer et al. 2011) establish that the public is able to understand the basic mechanics of SRM and readily identify concerns and issues that they believe need to be addressed.

Public engagement need not entail members of the public entering the lab and standing over the shoulders of scientists and engineers, but rather can simply involve facilitating processes whereby legitimate public concerns can be incorporated into decisions about the practice and governance of SRM research. Just as experts often feel that science is misunderstood by the public, so publics often feel ignored or misunderstood by experts (Wynne 2006). Rather than questioning scientific or technical expertise per se, the public typically wants to know that unrealistic assumptions about levels of predictability and control are not being made, that alternative framings and problem-definitions have been considered, and that decisions that will be highly consequential for society are not proceeding on the basis of a narrow set of framings or economic interests. For instance, previous engagement exercises in the UK and public perceptions research have revealed concerns about the relative "naturalness" of different SRM technologies, unease about the scale of interventions, concerns about the distribution of harms and benefits, a desire for governance mechanisms and transparency about research, and skepticism about the ultimate compatibility of SRM with democratic processes (Carr et al. 2012; Corner et al. 2012; Macnaghten and Szerszynski 2013). In order for the public to view engagement processes as legitimate, they need to know that scientists, engineers, and policymakers are ready to take such concerns seriously.

As Corner and Pidgeon (2010) and Corner et al. (2012) point out, public engagement on geoengineering faces the difficulties encountered by all attempts to include publics in decision-making processes. Such challenges include decisions about how engagement processes are structured, who participates, and how the results feed into policy-making processes by government officials, scientists, or the private sector. Additionally, attempts at public engagement must wrestle with the diversity of views on the role of the citizen relative to formal political decision-making in different countries around the world. In countries that embrace less democratic forms of governance, the public may not be conceptualized as having a legitimate say in policy-making and political culture might not enable meaningful dialogue. In the developing world, participatory practices can have the effect of strengthening the powerful and weakening other, complementary modes of democratic politics (Cooke and Kothari 2001). Even in long-running democracies, citizen participation and input into decision-making are variously envisioned, and practiced in ways that often only *appear* to treat the public as equal participants (Wynne 2006). Because of the global implications of SRM, public engagement would need to confront competing ideas about the role of the public relative to experts and decision-makers. And while it is tempting to simply call for additional engagements in well-established democracies in Europe or North America, public dialogue and participation needs to include more diverse and marginalized populations as soon as possible, to counter the dominance of Western perspectives in what should be a global discussion.

Conducting broad national and international engagements, particularly in developing nations where the greatest impacts (positive or negative) of SRM could be felt, certainly raises significant challenges. The enormous scale, the diversity of cultures and languages,

and the differences in political cultures, access to communication technology, and awareness and understanding of climate change and Western technology all present real barriers to public engagement. As public engagement efforts expand to a broader range of countries, we should not expect consistent methods and goals. Rather, the dynamic and emergent nature of politics, along with the diversity of political cultures, will likely result in a range of processes, that are haphazardly, opportunistically, and strategically stitched together to form an evolving global discourse. Some initiatives will emerge spontaneously in civil society, and perhaps take more unruly forms than those discussed here. Furthermore, if numerous engagements were carried out across the globe, public input would need to be synthesized and made usable for scientists, engineers, and policy makers. At the same time, some governments and interests will resist engagement efforts and seek to undermine them. While a disparate and non-uniform set of engagements may seem less than ideal, innovation and creativity has the potential to result in processes that are culturally relevant and politically feasible in different countries around the world.

A range of institutions could spearhead efforts, as the question of who should facilitate engagement and at what scale will be answered differently in different political and cultural contexts. Furthermore, we should expect considerable diversity in and across regions and countries, depending on who has the interest and capacity to implement engagement processes. For instance, in the UK, public engagement processes on geoengineering have thus far been largely funded by the national government through two research councils and carried out by academics, market research companies, and NGOs (Corner et al. 2012). Following this model, funding agencies in various countries, such as the National Science Foundation in the United States, could encourage or require future geoengineering research proposals to include public engagement exercises. Alternatively, professional societies or NGOs interested in promoting awareness and dialog around environmental and technological issues could initiate engagement efforts. The Royal Society, for instance, organized a small engagement process in conjunction with their 2009 geoengineering report. They have also coordinated with TWAS [the academy of sciences for the developing world], and the Environmental Defense Fund (EDF), to facilitate the ongoing Solar Radiation Management Governance Initiative (SRMGI), which has now conducted meetings in Africa and Asia aimed at expanding the discussion of SRM to include perspectives from the developing world (SRMGI 2013). While these meetings were not public engagement exercises as described above, SRMGI does indicate the possibility for innovative partnerships across government agencies, NGOs, and research societies to fund and initiate such processes in the future.

We suggest that engagement processes could, and will need to, scale up over time as scientific understanding and research and governance capacity builds (SRMGI 2013). Initial, small scale public engagement efforts such as focus groups in different parts of the world could begin to spotlight the different perspectives of diverse populations. Over time, engagement processes should expand, include more diverse groups and better reflect and represent both the global population and a broader range of views therein. Throughout this process, interdisciplinary research teams will need to work with governments, civil society groups (such as environmental NGOs), and citizens to develop effective engagement methods sensitive to different political and cultural systems, while also working to better integrate the information generated in public engagement exercises into the development of SRM technologies and policies.

A range of engagement methods have been developed in the past decade and could be employed across a variety of political and cultural systems around the world (Rowe and Frewer 2005). For instance, in several European parliamentary systems, upstream public

engagement has proven a particularly useful tool, eliciting public views in advance of and in coordination with decision-making by elected representatives. In the United States, where citizens have multiple avenues through which to influence decision-making beyond electoral processes, such as litigation, ballot initiatives, lobbying, and comments during administrative rule-making, innovative stakeholder processes have emerged, including citizen-initiated collaborative groups that could be utilized to link stakeholder processes directly to decision-makers and/or legislation and regulatory rule-making (Dryzek and Tucker 2008). These engagement methods will undoubtedly need to be adapted or new and innovative forms of engagement developed to be effective in non-Western contexts. Examples of this type of adaptation exist, such as the use of citizen's juries in India and Zimbabwe to include subsistence farmers in discussions about genetically modified crops (Rusike 2005).

Despite potential difficulties, the scale and scope of current SRM proposals make the alternatives to open and inclusive international deliberation, such as decisions made solely by scientists and policy makers in a small group of countries, unacceptable. Even existing national and supranational institutions of representative democracy may struggle to command sufficient legitimacy to make decisions about willfully manipulating the global climate through either large-scale testing or deployment of SRM. Such decisions have the potential to shape our collective future and therefore must incorporate the views and concerns of the diverse publics that inhabit this planet to be ethically, politically, socially, and technologically legitimate and robust. From a normative perspective, public engagement exercises help satisfy moral requirements for participation by affected parties. From an instrumental perspective, early awareness of public concerns can produce a better understanding of how to ensure that public engagement exercises connect with the sort of issues and concerns that people have about SRM. From a substantive perspective, engagement with diverse publics will ensure that decisions about SRM research and its possible deployment are informed by a broader set of perspectives and priorities, and are thus more likely to serve the needs of the world's various populations. Because diverse publics currently appear ready, willing, and able to engage with the topic of SRM, and because public engagement processes hold the potential to improve SRM technologies and policies, we suggest that public engagement should be a mandatory component of any nationally or internationally funded research program on SRM.

Acknowledgments This work was supported by the US National Science Foundation (grant number SES 0958095) and the Center for Climate and Energy Decision Making (SES-0949710), through a cooperative agreement between the National Science Foundation, Carnegie Mellon University, and the Fund for Innovative Climate and Energy Research. W.C. is funded by a US Environmental Protection Agency STAR PhD Fellowship. The authors would like to thank Maialen Galarraga, Phil Macnaghten, and the anonymous reviewers for their helpful comments on earlier drafts.

References

BPC (2011) Geoengineering: A national strategic plan for research on the potential effectiveness, feasibility, and consequences of climate remediation technologies. Bipartisan Policy Center's Task Force on Climate Remediation

Carr W, Mercer A, Palmer C (2012) Public concerns about the ethics of solar radiation management. In: Preston CJ (ed) Engineering the climate: The ethics of solar radiation management. Lexington Books, Lahham, pp 169–186

Cooke B, Kothari U (2001) Participation: The new tyranny? Zed Books, London

Corner A, Pidgeon N (2010) Geoengineering the climate: the social and ethical implications. Environment 52(1):24–37

Corner A, Pidgeon N, Parkhill K (2012) Perceptions of geoengineering: public attitudes, stakeholder perspectives, and the challenge of 'upstream' engagement. Wiley Interdisc Rev Clim Chang 3(5):451–466
Crutzen P (2006) Albedo enhancement by stratospheric sulfur injections: a contribution to resolve a policy dilemma? Clim Chang 77(3):211–220
Delgado A, Lein Kjølberg K, Wickson F (2011) Public engagement coming of age: from theory to practice in STS encounters with nanotechnology. Public Underst Sci 20(6):826–845
Dryzek JS, Tucker A (2008) Deliberative innovation to different effect: consensus conferences in Denmark, France, and the United States. Public Admin Rev 68(5):864–876
European Commission (2002) Science and society: Action plan. European Commission, Luxembourg
Fiorino DJ (1990) Citizen participation and environmental risk: a survey of institutional mechanisms. Sci Tech Hum Val 15(2):226–243
Galarraga M, Szerszynski B (forthcoming) Geoengineering knowledge: interdisciplinarity and the shaping of climate engineering research. Environ Plan A
Grove-White R, Macnaghten P, Wynne B (2000) Wising up: The public and new technologies. Centre for the Study of Environmental Change, Lancaster University, Lancaster, http://www.csec.lancs.ac.uk/docs/wising_upmacnaghten.pdf
House of Commons (2010) The regulation of geoengineering. Science and Technology Committee. Fifth report of the session 2009–2010 (HC221)
House of Lords (2000) Science and society: Third report. Select Committee on Science and Technology, London
Hulme M (2010) Climate intervention schemes could be undone by geopolitics. Yale Environ 360: http://e360.yale.edu/author/Mike_Hulme/84/
IPCC (2007) Climate change 2007: The fourth assessment report of the intergovernmental panel on climate change. IPCC, Cambridge
Kearnes M, Macnaghten P, Wilsdon J (2006) Governing the nanoscale: Peoples, policies, and emerging technologies. Demos, London
Keith DW (2000) Geoengineering the climate: history and prospect. Annu Rev Energ Environ 25(1):245
Kitcher P (2001) Science, truth, and democracy. Oxford University Press, New York
Leshner AI (2003) Public engagement with science. Science 299(5609):977
Longino H (1990) Science as social knowledge: Values and objectivity in science and social inquiry. Princeton University Press, Princeton
Macnaghten P, Kearnes MB, Wynne B (2005) Nanotechnology, governance, and public deliberation: what role for the social sciences? Sci Commun 27(2):268–291
Macnaghten P, Szerszynski B (2013) Living the global social experiment: an analysis of public discourse on geoengineering and its implications for governance. Glob Environ Chang. doi:10.1016/j.gloenvcha.2012.12.008, published online 21 January 2013
Marris C, Wynne B, Simmons P, Weldon S (2001) Public perceptions of agricultural biotechnologies in Europe. Final report of the PABE Research project, http://www.lancs.ac.uk/depts/ieppp/pabe/docs.htm
Mercer AM, Keith D, Sharp JD (2011) Public understanding of solar radiation management. Environ Res Lett 6(4):044006
Moreno-Cruz J, Ricke K, Keith D (2012) A simple model to account for regional inequalities in the effectiveness of solar radiation management. Clim Chang 110(3):649–668
Olson R (2011) Geoengineering for decision makers. Woodrow Wilson International Center for Scholars, Washington, D.C
Pongratz J, Lobell DB, Cao L, Caldeira K (2012) Crop yields in a geoengineered climate. Nat Clim Chang 2(2):101–105
Preston C (2012) Solar radiation management and vulnerable populations: The moral deficit and its prospects. In: Preston CJ (ed) Engineering the climate: The ethics of solar radiation management. Lexington Books, Lanham, pp. 77–93
Rayner S, Redgewell C, Savulescu J, Pidgeon N, Kruger T (2009) Memorandum on draft principles for the conduct of geoengineering research, (the 'Oxford Principles') reproduced in House of Commons Science and Technology Committee, The regulation of geoengineering, fifth report of the session 2009-10, report together with formal minutes, oral and written evidence, (HC221), 18 March 2010. www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/221.pdf
Rayner S, Heyward C, Kruger T, Pidgeon N, Redgwell C, Savulescu J (2013) The Oxford Principles. Climatic Change. doi:10.1007/s10584-012-0675-2
Ricke KL, Morgan MG, Allen MR (2010) Regional climate response to solar-radiation management. Nat Geosci 3(8):537–541
Robock A, Oman L, Stenchikov GL (2008) Regional climate responses to geoengineering with tropical and Arctic SO_2 injections. J Geophys Res: Atmospheres, 113(D16), D16101
Rowe G, Frewer LJ (2005) A typology of public engagement mechanisms. Sci Tech Hum Val 30(2):251–290

Royal Society (2004) Nanoscience and nanotechnologies: Opportunities and uncertainties. The Royal Society, London

Royal Society (2009) Geoengineering the climate: Science, governance, and uncertainty. The Royal Society, London

Rusike E (2005) Exploring food and farming futures in Zimbabwe: A citizens' jury and scenario workshop experiment. In: Leach M, Scoones I, Wynne B (eds) Science and citizens: Globalization and the challenge of engagement. Zed Books, London

Sarewitz D, Nelson R (2008) Three rules for technological fixes. Nature 456(18):671–872

Scott D (2012) Insurance policy or technological fix? The ethical implications of framing solar radiation management. In: Preston CJ (ed) Engineering the climate: The ethics of solar radiation management. Lexington Books, Lahham, pp. 151–168

Shue H (1992) The unavoidability of justice. In: Hurrell A, Kingsbury B (eds) International politics of the environment : Actors, interests and institutions. Oxford University Press, New York, pp 373–397

SRMGI (2013) Solar radiation management: The governance of research. Environmental Defense Fund, The Royal Society, TWAS. http://www.srmgi.org/

Stilgoe J (2011) A question of intent. Nat Clim Chang 1:325–326

Stilgoe J, Wilsdon J (2007) The rules of engagement: Dialogue and democracy in creating nanotechnology futures. In: Allhoff F, Lin P, Moor J, Weckert J (eds) Nanoethics: The ethical and societal implications of nanotechnology. Wiley, Hoboken, pp 241–249

Stirling A (2005) Opening up or closing down? Analysis, participation, and power in the social appraisal of technology. In: Leach M, Scoones I, Wynne B (eds) Science and citizens: Globalization and the challenge of engagement. Zed Books, London, pp 218–231

Wilsdon J, Willis R (2004) See-through science: Why public engagement needs to move upstream. Demos, London

Wynne B (2006) Public engagement as a means of restoring public trust in science: hitting the notes but missing the music. Community Genet 9:211–220