GEOENGINEERING THE CLIMATE:

THE SOCIAL AND ETHICAL IMPLICATIONS

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"The acceptability of geoengineering will be determined as much by social, legal, and political issues as by scientific and technical factors"[1]

Preventing Dangerous Climate Change

Anthropogenic climate change is now a global political priority, and governments across the world are devising policies aimed at mitigating greenhouse gas emissions from human activities. This upsurge in political activity reflects the increasing scientific consensus that the effect of unmitigated climate change for human and non-human systems will be overwhelmingly negative.[2] The effects of accelerated climatic change are already being observed at the polar ice caps.[3] With the United Nations negotiations in December 2009 in Copenhagen a focal point for policymakers everywhere, discussion no longer centers on whether climate change should be tackled, but how.

Typically, policies are aimed at preventing what the 1992 United Nations Framework Convention on Climate Change (UNFCCC) referred to as dangerous anthropogenic interference with the climate system. Although there are significant difficulties in defining what constitutes "dangerous" climate change,[4] a strong international consensus has emerged that says that preventing a rise in global temperatures of more than two degrees Celsius above pre-industrial revolution levels is critical (corresponding to a level of carbon dioxide in the atmosphere of approximately 450 parts per million). Beyond this level, feedback loops in the climate system become increasingly likely—and the threat of relatively rapid and catastrophic changes becomes significantly greater.

Unfortunately, the increasing attention paid to mitigating dangerous climate change has not prevented a continuing rise in global greenhouse gas emissions. In fact, emissions are increasing more rapidly than even the worst case scenario modeled by the Intergovernmental Panel on Climate Change (IPCC), and predictions about the likely effects of anthropogenic influence on the climate have become increasingly severe.[5] The global population continues to rise (particularly in emerging economies such as China and India), along with the per-capita emissions of many millions of people.

It remains to be seen whether global temperatures will exceed the two-degrees limit. But some anthropogenic climate change has already occurred (global temperatures have risen by around 0.74 degrees Celsius in the last 100 years) and because of the inertia in the climate system, a further warming of approximately 0.6 degrees Celsius is inevitable.[6] Thus, the window for effectively mitigating against a two-degree rise in global temperatures is extremely narrow, and many prominent members of the climate science community have begun to question whether preventing a rise in global temperatures of this magnitude (or even greater) is possible using existing mitigation approaches.[7] Scientists and policymakers are increasingly asking what will happen if the two-degrees "guardrail" is breached, particularly if temperature increases in excess of two degrees lead to positive feedback loops and further accelerate climate change. Are existing mitigation and adaptation policies enough to prevent catastrophic changes in the climate from occurring? In this context, geoengineering the earth's climate has started to be considered as a serious candidate for both mitigating against and adapting to dangerous climate change.

Geoengineering

Geoengineering refers to the intentional manipulation of the earth's climate to counteract anthropogenic climate change or its warming effects.[8] Most of the technology implicated in geoengineering proposals has yet to be developed, let alone field tested. Some geoengineering proposals may yet turn out to be little more than imaginative science fiction—for now, geoengineering is at a pre-research and development phase, with no major research initiatives yet undertaken. But geoengineering is beginning to be taken seriously by scientists around the world, including the American Meteorological Society and the UK's Royal Society.[9]

In the most comprehensive review of geoengineering science to date, the Royal Society identified two distinct approaches: carbon dioxide removal (CDR) techniques, which remove CO_2 from the atmosphere, and solar radiation management (SRM) techniques, which reflect a small percentage of the sun's light and heat back into space.[10] CDR techniques include proposals to imitate trees' sequestration of carbon dioxide from the atmosphere by using giant chemical vents to "scrub" the atmosphere (analogous to the carbon capture and storage techniques currently being developed for use on coal-fired power stations) and plans to "fertilize" the oceans by using particles of iron sulphate to stimulate algal blooms (which absorb carbon dioxide). Although not strictly an engineering intervention, major global reforestation could also be viewed as a long-term method for CDR. By contrast, SRM techniques include suggestions for the placement of trillions of tiny "sunshades" in orbit around the earth to deflect a percentage of solar radiation, and the enhancement of marine cloud albedo using particles of sea salt to deflect sunlight. (See Sidebar, "Proposed Approaches to Geoengineering" for further technical detail on geoengineering proposals.)

The Royal Society report included a preliminary assessment of the technical feasibility and safety of specific geoengineering proposals. The uncertainties are considerable, and the potential risks vary enormously across different proposals—from concerns that SRM techniques would do nothing to prevent ocean acidification to fears that ocean fertilization techniques would have unpredictable (and undesirable) ecological side effects. More generally, there are significant concerns about the masking effects of some geoengineering approaches. In particular, SRM techniques do not address the underlying causes of climate change (i.e., the build up of greenhouse gases), and were such a program to unexpectedly fail, a rapid acceleration of warming might then ensue. Figure 1 (reproduced from the Royal Society report) represents an initial attempt to evaluate a number of geoengineering techniques. According to the Society's analysis, it is clear that there is substantial variation in the estimates of the cost, effectiveness, timeliness, and risk of putative geoengineering approaches. A key consideration is that many of the risks of geoengineering are at present highly uncertain (effectively "unknown unknowns"), making them particularly difficult to analyze through conventional risk assessment techniques.

The Royal Society emphasized that none of the current proposals for geoengineering should currently be considered as acceptable policy responses to climate change. However, despite distancing itself from the application of geoengineering techniques, the Royal Society recommended that £10 million be invested annually into research on their technical feasibility and safety over the next 10 years (in the UK). As a result, the UK Research Councils plan to spend £3 million on some preliminary research from late 2010 onward. Thus, despite the obvious wariness with which geoengineering proposals are treated by some members of the scientific community,[11] research into the technical feasibility and physical risks of geoengineering is poised to begin.

The considerable uncertainty surrounding geoengineering is of course not confined to questions of technical risk and feasibility. The prospect of coordinated and large-scale attempts to engineer the climate raises a host of challenging legal, ethical, and social questions. One of the key recommendations in the Royal Society report was that a process of dialogue and engagement to explore public and civil society attitudes, concerns, and uncertainties about geoengineering should begin immediately. In the following section, we identify some of the social and ethical questions that geoengineering proposals may raise. We then identify some methods by which public responses to these questions might be elicited. Finally, and echoing the Royal Society's sentiments, we suggest that beginning a process of legitimate and participative public engagement is essential for policymakers who are considering proposals for geoengineering the climate. As an issue potentially affecting citizens of countries around the globe—both rich and poor—dialogue about the prospect of engineering the earth's climate should not be confined to technical or political elites, nor for that matter solely to the citizens of industrialized Western nations.

Proposed Approaches to Geoengineering

The Royal Society has identified two broad types of geo-engineering proposals. Carbon dioxide removal (CDR) techniques remove CO_2 from the atmosphere, while solar radiation management (SRM) techniques reflect a small percentage of the sun's light and heat back into space.

CDR TECHNIQUES

Chemical air capture and carbon sequestration: There are a number of proposals to imitate trees' sequestration of carbon dioxide from the atmosphere by using giant chemical vents to "scrub" the atmosphere. More conventional carbon capture and storage (CCS) techniques are currently being developed for use on coal-fired power stations.

Ocean fertilization: Plans to "fertilize" the oceans by using particles of iron to stimulate algal blooms (which absorb carbon dioxide) have already attracted interest from commercial investors, but small scale experiments have thus far been unsuccessful.

Biomass/biochar/biomass with carbon sequestration (BECS): The use of biofuels as a substitute for fossil fuels might not seem to qualify as geoengineering, but the mass harvesting and sequestration of biomass would constitute a major climatic intervention.

Enhanced weathering: Adding silicate materials to soil would enhance weathering processes which naturally sequester CO_2, while increasing the levels of alkalinity in the ocean would have a similar effect.

Afforestation: Large-scale ecosystem management at a local and global level could provide significant increases in carbon sinks such as forests. While few undesirable side effects would be expected, carbon stored in vegetation is not securely sequestered in the long term.

SRM TECHNIQUES

Space-based reflectors: The placement of a fleet of artificial "sunshades" in orbit around the earth would deflect solar radiation. One suggestion is that a swarm of around 10 trillion extremely thin discs could be launched into space in stacks of a million, once every minute, for about 30 years.

Stratospheric aerosols: Sulphate particles blasted into the stratosphere would deflect sunlight. Based on the model of a volcano, rapid reductions could be achieved in earth-bound solar radiation, but there are serious concerns over unintended effects on the stratospheric ozone.

Enhanced surface albedo: Human settlements could be made more reflective by painting them white, more reflective crop varieties and grassland could be planted, and deserts could be covered with highly reflective materials.

Enhanced cloud albedo: The whitening of oceanic clouds could be achieved by spraying salt-rich sea water into the sky—sometimes referred to as "cloud seeding."

Figure 1. A preliminary evaluation of geoengineering techniques reviewed by The Royal Society (2009)

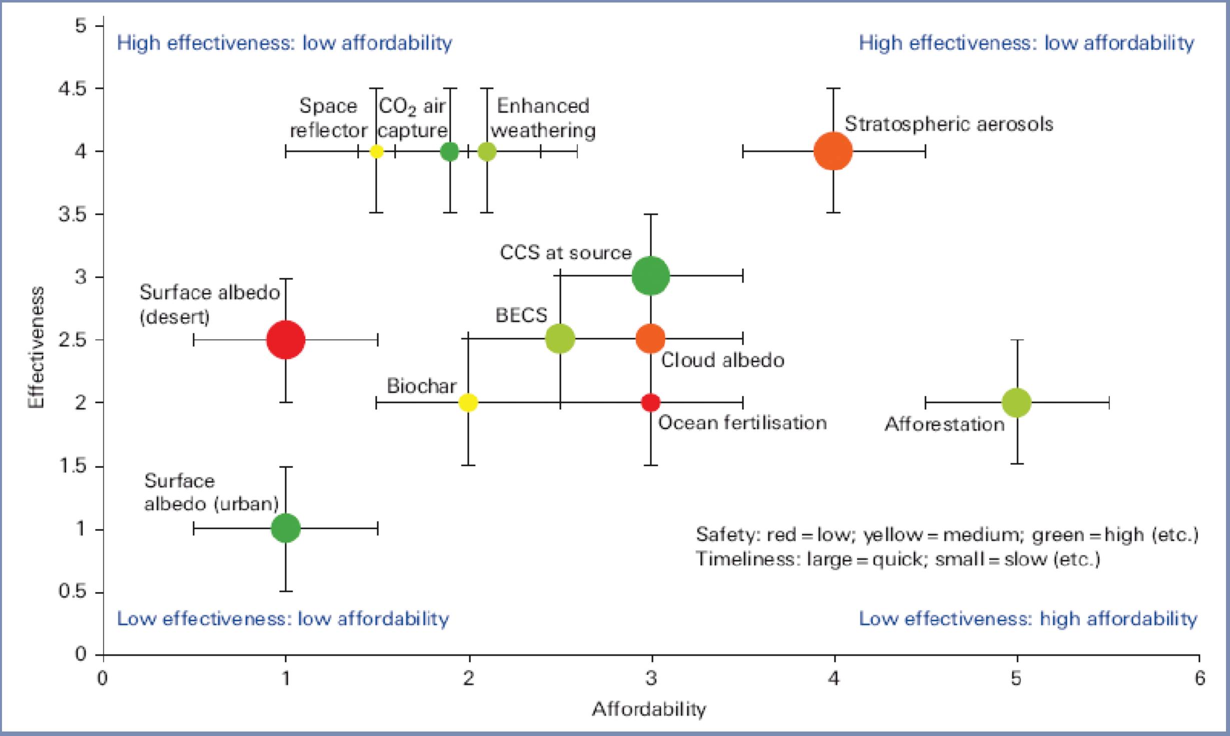

Figure reproduced with full permission from The Royal Society. Geoengineering the Climate: Science, Governance and Uncertainty (Science Policy Centre Report 10/09, 2009, p. 49). Each of the geoengineering techniques is described in the Sidebar, "Proposed Approaches to Geoengineering."

An additional dimension on which geoengineering techniques vary is reversibility. While increasing urban surface albedo could quickly be undone, reversing ocean fertilization programs would be more difficult. The degree to which any particular geoengineeing technique could be halted and reversed might be a critical determinant of how people perceive them.

The Social and Ethical Implications of Geoengineering

Intentional Manipulation of the Global Climate

Perhaps the most fundamental question that geoengineering raises is whether the intentional manipulation of the global climate is ethically acceptable. On the one hand, few would disagree that a global temperature rise of three or four degrees (or even higher) will have catastrophic consequences for both people and ecosystems, providing an ethical imperative for action if all other options are likely to fail. There is also a long history of anthropogenic manipulation or modification of many of the Earth's systems (not just the global climate).[12] It is clear that humans have the capacity to geoengineer and have done so intentionally on a small scale and unintentionally on a large scale on many previous occasions: Anthropogenic interference in the global climate is precisely the problem that geoengineering is designed to solve.

But the intentional large scale manipulation of the climate has not previously been attempted. Thus, it is the intentionality of geoengineering proposals that demarcates them from previous anthropogenic interference in the global climate. This asymmetry between intended and unintended acts is clearly observed in law (most legal systems distinguish crimes on the basis of intentionality), medical ethics (passive vs. active euthanasia), and military conduct (the intentional killing of civilians vs. "collateral damage" of war).[13]

Some commentators have argued that the fact that humans have already caused climatic change is precisely the reason why an intentional effort to undo it should not be initiated.[14] On this view, the unintended consequences of current human interference in the climate system are a powerful indication that "meddling" with the global climate is inadvisable. Proponents of geoengineering counter that even non-geoengineering attempts at mitigation constitute intentional interference in the climate—as efforts to reduce the greenhouse gas emissions of human activity are aimed at slowing down (and ultimately reversing) global warming.[15] But as several decades of risk research have established, people's perceptions of the risks associated with science and technology are filtered through social and cultural lenses.[16] This means that the prospect of large-scale technological manipulation of the atmosphere is likely to produce radically different responses from different members of the public. People with opposing cultural worldviews tend to perceive risks and benefits very differently.[17] While some may find the prospect of large-scale engineering projects worrisome, others will view programs aimed at changing their consumption morally unacceptable. While mitigation through behavior change—for some closer to an idea of "social engineering"—and geoengineering may both technically constitute intentional interference with the climate, people are unlikely to see the commonality.[18]

Consent

If agreement were to be reached that climate modification was a technically viable and politically acceptable option, whose agreement would be sought? In the industrialized nations, the democratization (or otherwise) of science and technology is a topic of continuing interest. As the large academic literature on how to engage people with science demonstrates, *how and why* to involve the public in decisions about the appropriateness or acceptability of novel scientific and technological developments continues to generate debate.[19] The U.S. National Research Council (in common with many others) has argued that it is beneficial for experts and policymakers to involve citizens in discussion about the societal aspects of emerging areas of science, technology, and the environment using appropriate analytic-deliberative processes at the earliest possible stage.[20] The prospect of controlling the global thermostat is something that all citizens could reasonably claim to have a legitimate stake in. How will the public's views be adequately represented?

The issue of consent arguably has more profound implications internationally. It is well documented that some of the poorest parts of the world (e.g., Bangladesh, sub-Saharan Africa, and the Pacific Island states) will be disproportionally affected by climate change—both because of their resource-limited capacity to cope with the changing climate, and because of their low-lying or drought-prone geography. Just as the citizens of developing countries did little to contribute to the adverse effects of the climate change that they now face, it seems unlikely that the poorest people in the poorest countries will be adequately represented in decisions about geoengineering.[21] Yet perversely, any adverse consequences of geoengineering are likely to be more difficult to address in nations with limited financial resources. Recognizing this concern, the Royal Society recommended that it would be inadvisable to pursue geoengineering methods that would have effects extending beyond national boundaries (e.g., the deployment of sulphate aerosols) before appropriate governance mechanisms were in place. The history of international climate negotiations is of course fraught with difficulties, suggesting that in practice, geo-governance mechanisms will be difficult to design and implement.

A more mundane issue of consent arises from the literature on public attitudes towards nuclear power. Recent studies in the UK have asked people about their views on nuclear power, in light of the threat posed by climate change. While outright support and strong opposition to nuclear power was evident, a significant proportion of participants offered a "reluctant acceptance"—that is, they agreed that nuclear power (as a potential source of low-carbon energy) could be a necessary evil in the fight against climate change.[22] A key conclusion of the research was that this was a conditional, unstable attitude position with considerable ambivalence associated with the apparent support. In addition, participants in qualitative discussion groups expressed resistance to the pre-framing of 'nuclear vs. climate change' rather than 'nuclear vs. other energy options that might fight climate change'. Geoengineering is being advocated in precisely this way—as the lesser of two evils. If a narrative of inevitability is used to frame geoengineering without fully evaluating its merits against other policy options first, what effect will this have on public acceptance of it?[23]

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Some scientists have proposed carbon dioxide removal systems to address pollutants emitted by refineries such as this one.

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Tree seedlings being grown for a reforestation project in Africa.

Global Security & Law

Research on geoengineering has its roots in military strategies developed for weather modification.[24] Both the United States and Russia expressed significant interest (and invested significant funds) in researching weather modification for the purposes of military conflict. However, concern over this type of research led to the Environmental Modification Convention (passed by the United Nations in 1977), banning the use of weather modification for military or other hostile use. Some commentators have suggested that geoengineering proposals might violate the terms of this treaty.[25]

While geoengineering's military history does not preclude benevolent uses, it is clear that climate modification schemes come with a potential for global conflict that should be taken seriously by policymakers. Conflict might arise if the world views a nation pursuing a climate modification program as placing its own interests above those of other nations. It is even conceivable that a wealthy individual or private company might develop geoengineering technologies. But even if multilateral agreement could be reached, the potential for conflict would remain. What if, in the process of improving the climate of its own country, a government inadvertently affected the climate of another? What if one nation attributed a change in its climate to the geoengineering program of another, or even instigated a counter-program (to add greenhouse gases to the atmosphere) if the geoengineering program of another nation was felt to inadvertently affect it?[26]

Picking apart the climatic effects that could be attributed to a rival nation's geoengineering from those which would have occurred naturally would be extremely difficult. The scope for conflict—even in the absence of intentional provocation—would be significant. While similar disputes might be envisioned over the uneven distribution of climatic changes from unabated greenhouse gas emissions, the act of geoengineering might well be considered more problematic than doing nothing. Finally, even if conflict could be avoided in the initiation of geoengineering proposals, significant questions remain about whether the world's nations could create and maintain the centuries of global political stability that would be required to manage such industrial projects on a global scale. As the climate scientist Stephen Schneider succinctly puts it, "Just imagine if we needed to do all this in 1900 and then the rest of the 20th century unfolded as it actually did!"[27]

Distraction from Mitigation and the Lure of "Techno-Fixes"

The commercial potential of geoengineering has already attracted interest from private investors,[28] but initial research into geoengineering will almost certainly be initiated by government-funded research councils. Geoengineering proposals will compete with other mitigation and adaptation strategies for research investment, which will raise questions about the allocation of sparse government resources.[29] In fact, some pressure groups that have previously been vocal opponents of stringent political action to reduce greenhouse gases (such as the Cato Institute in the United States) have indicated their support for geoengineering as a "cost effective" method of tackling climate change.[30] Advocates argue that the cost of geoengineering—in terms of gross domestic product—is substantially less than other mitigation options (although the ETC Group has dubbed geoengineering the "Big Mac" of climate change responses—fast, unhealthy, and deceptively cheap in the short term).[31] This suggests that as awareness of geoengineering's potential grows, some powerful economic and ideological interests will lobby strongly for it. At a political level, therefore, geoengineering might be considered a dangerous distraction (with momentum of its own) from the task of mitigation through more traditional methods of emissions reductions. The Royal Society refers to this as a "moral hazard" argument—the phenomenon whereby people who feel "insured" against a risk may take greater risks (i.e., mitigate less) than they would otherwise be prepared to take.[32] Of course, whether geoengineering will suppress individual and group incentives for action (or alternatively galvanize some sections of society) is an empirical issue, pointing to the need for quite subtle social research on geoengineering's impact on attitudes to climate change, as well as behavioral intentions and responses.

Geoengineering also does nothing to challenge the systems of production and consumption that might be considered unsustainable for reasons other than the greenhouse gas emissions associated with them. For example, the UK Energy Research Center recently warned that conventional oil supplies could peak by 2020 if current consumption trends continue.[33] While proposals for capturing carbon dioxide and storing it underground can mitigate levels of CO_2 in the atmosphere, oil reserves will continue to be depleted for as long as fossil fuels continue to be burned. Similarly, increasing numbers of commentators and economists have questioned whether the globally dominant economic model of consumption-based growth can deliver a truly sustainable society, given that the decoupling of economic growth and energy use is typically relative, not absolute.[34] To what extent will the promise of geoengineering detract attention from the critical need to establish more sustainable consumption and production patterns across the globe?

As the climate scientist Mike Hulme has observed, questions such as these shed light on the deep ideological divides that run through debates about climate change and how to "solve" it.[35] For groups and individuals who see climate change as the symptom of a social and economic order that is inherently unsustainable, geoengineering represents the worst kind of techno-fix. These people may desire social change independent from concern about climate change—and are thus likely to view proposals that do not address existing inequalities between nations and peoples with suspicion. Conversely, those who place faith in the human capacity for finding technological solutions to environmental and other problems might well see geoengineering as a genuine opportunity rather than a threat. Here, deeply held and culturally ingrained narratives regarding human dominance over (or conversely interconnectedness with) nature are likely to play a role.

As knowledge of geoengineering proposals proliferates, the metaphors that emerge in the public discourse (and how they relate to different underlying political and environmental ideologies) will be telling. The recently completed European nanotechnology project DEEPEN[36] found that among discussion groups in the UK and Portugal, five key narratives characterized participants' responses to nanotechnology: 1) "be careful what you wish for"; 2) "opening Pandora's box"; 3) "messing with nature"; 4) "kept in the dark"; and 5) "the rich get richer and the poor get poorer." Interestingly, the technoscientific vision of technology as driving inexorably forward and bringing inevitable social benefits tended to be rejected. These narratives resonate with the sorts of responses that might be expected towards geoengineering, and suggest that there are clear parallels between these two emerging areas of science and technology (a theme that we develop in more detail below).[36]

While proposals for capturing carbon dioxide and storing it underground can mitigate levels of CO_2 in the atmosphere, oil reserves will continue to be depleted for as long as fossil fuels continue to be burned.

Unintended Consequences

Concerns about whether scientists and engineers have the capacity to safely mitigate the unintended technical and environmental consequences of geoengineering will play a central role in the debate. But the issue of unintended consequences also has a number of social dimensions. For example, history shows us that complex technical and environmental systems often fail because of unanticipated interactions between their component parts, while the processes of societal oversight typically are insufficiently sensitive to emerging warning signs.[37] In an analysis that broadly supports pursuing geoengineering research, James Lovelock questioned whether human societies are sufficiently talented to take on the role of permanently regulating the global thermostat: "Consider what might happen if we start by using a stratospheric aerosol to ameliorate global heating; even if it succeeds, it would not be long before we face the additional problem of ocean acidification. This would need another medicine, and so on. We could find ourselves in a Kafka-like world from which there is no escape."[38]

Lovelock's "Kafka-like world" is purposefully dramatic. But the notion that embarking on a course of geoengineering could result in perpetual technological "treatments" for the climate system is one that should be taken seriously. Aside from the moral questions it raises about what this sort of society and global environment would be like, an increasingly technologically sophisticated future may not be something that can be taken for granted. Rapid technological progress since the industrial revolution has been inextricably linked to the availability of cheap and plentiful fossil fuels. Will a post-carbon energy future be similarly catalytic in driving technological innovation?

The ethical and social questions we have identified are not intended to be an exhaustive list, and neither are they predictions about the likely trajectory of public and ethical opinion towards geoengineering. Inevitably, in focussing on the disputes that geoengineering might raise, we have not discussed in detail the benefits that proponents of geoengineering research foresee. The worst effects of geoengineering may pale in comparison to the threats posed by insufficiently mitigated climate change. And, if at some critical juncture in the future the survival of the human race depended on our ability to geoengineer a climate solution, proponents of geoengineering research argue that it would be better if we had already done the fundamental research.[39]

The promise of a benignly controlled climate may be appealing to some, although most see geoengineering as a contingency plan—a backup in case all else fails. But even proponents of geoengineering research urge caution in pursuing such a radical agenda because the social and ethical issues at stake are substantial. In the next section, we outline some possible methods for beginning a process of upstream engagement with members of the public. By drawing on relevant public engagement research on another emerging area of science—nanotechnology—we seek to identify ways to establish a dialogue with society at large that may, if approached open-mindedly, provide a legitimate method for addressing broader questions about geoengineering.

Some Approaches to Upstream Engagement

DIRECT PUBLIC ENGAGEMENT

Citizens' juries, panels, focus groups, and deliberative workshops can allow significant ethical concerns to be identified and "desired futures" to be discussed. We argue that an international process of direct engagement with the public on geoengineering should be initiated immediately–ideally prior to the commencement of a physical research program.

SCENARIO ANALYSIS WITH STAKEHOLDERS

Identifying different directions that a new technology might take can help to identify significant uncertainties. Mapping out some possible trajectories for geoengineering might permit some of the ethical issues we identify to come to the forefront.

DECISION ANALYTIC METHODS

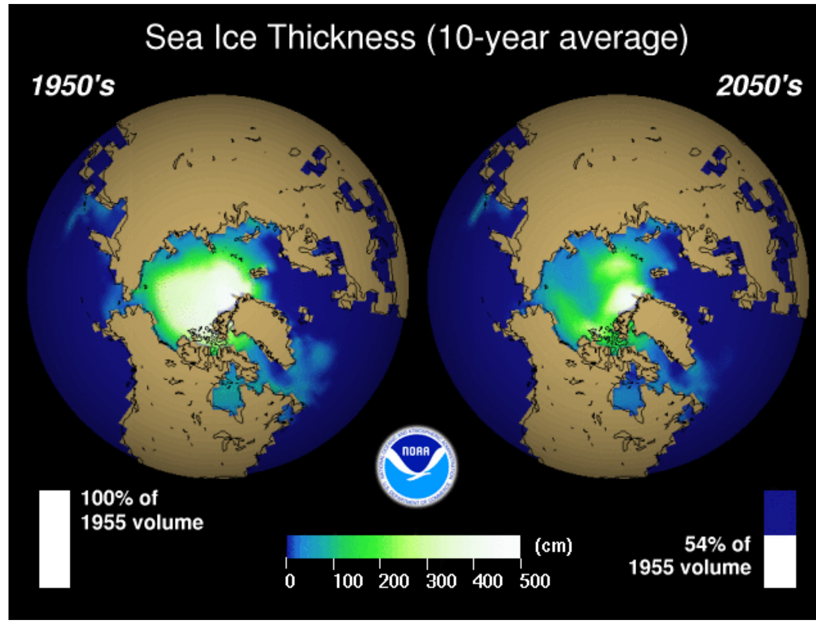
Decision analytic methods consist of working with stakeholders or the public to identify the frames and values that are ultimately necessary for characterizing risks. Geoengineering is likely to be framed using an initial narrative of necessity or inevitability. What effect will this have on judgments? Can alternative decision structures be identified?

MULTISTAGE METHODS

Multistage methods combine different approaches to framing and risk assessment in a sequence of linked activities, often with different groups of stakeholders and the public, and at different times. It seems likely that multistage and multi-audience methods will be necessary to establish a legitimate process of international engagement on geoengineering.

Involving Citizens Early in Debate: The Challenge of Upstream Public Engagement

"Public engagement" is typically poorly specified.[40] 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. Debate over the best way to involve members of the public in decisions related to science and technology has taken place for over a decade.[41] Early discussions centered around the deficit model of science communication, which assumed that the public had a deficit of knowledge that needed to be addressed through engagement. But the deficit hypothesis has been discredited by both theoretical advances and empirical data. From a theoretical perspective, assuming a deficit of knowledge is not conducive to establishing a genuinely participatory interaction between scientists, communicators, and the broader public. And from an empirical perspective, studies have consistently shown that people's perception and acceptance of science and technology is not straightforwardly attributable to their level of knowledge about it.[42] The rejection of the deficit model of science communication has been accompanied by a concerted effort to develop more deliberative public engagement mechanisms, and to move their use "upstream" in the research and development process. A technology is upstream if significant research and development has not yet begun, public controversy about the topic is not currently present, and entrenched attitudes or social representations have not yet been established (criteria that seem to fit geoengineering's current position). Upstream engagement means encouraging the public to play an active role in deliberating a scientific or technological issue throughout the entire process of scientific research and development, and particularly before significant commercial realization has taken place.[43]



ISTOCKPHOTO/KTSIMAGE

Reduced sea ice thickness is just one of the many signs of global climate change.

Successful upstream engagement requires finding new ways of listening to and valuing diverse forms of public knowledge and social intelligence, and involving the public in more fundamental questions about the pace and direction of science and technology (and the wider values that inform this). Many authors have issued calls for the social scientific (as well as technical) aspects of new technologies to be addressed early and simultaneously, rather than simply allocating the impacts or societal effects of a new technology to the social sciences to assess *post hoc*.[44] On this view, social and ethical assessments of a new technology must occur in real time in order to address deeper social and political questions about purpose, ownership, control, and responsibility: What is a development for, what is the need, who owns it, and who will be responsible if things go wrong? All of these questions seem especially pertinent for any future proposals to geoengineer the climate.

Interest in upstream engagement in Europe can be partly attributed to the widely held perception that public engagement over genetically modified organisms (GMOs) came too late, and resulted in something of a backlash.[45] The lessons learned and the approaches used in projects such as the British GM Nation public debate in 2003 have informed much of the research and practice in Europe that has followed it.[46] But most of the discussion over methods of upstream engagement has related to currently upstream topics (for example, nanotechnology, hydrogen energy technologies, and synthetic biology). Tee Rogers-Hayden and Nick Pidgeon have referred to nanotechnology—the manufacture of nanoscale structures and devices that have novel chemical and electrical properties—as the test case for upstream engagement. A number of engagement mechanisms, and their potential for upstream engagement on geoengineering are outlined in the Sidebar, "Some Approaches to Upstream Engagement."[47] Several methods emerge as promising ways to develop an upstream dialogue with the public, and we focus here on the use of citizens' juries and deliberative workshops.[48]

Citizens' juries are a forum for public debate and discussion, and are based on the model of a legal jury (and are related to the "consensus conference" models used in Australia and Scandinavian countries).[49] They are semi-structured and participatory sessions, where a representative group of the public is asked to consider a series of questions relating to a particular topic. The jury has the opportunity to question "witnesses" (experts in the field) and are asked to reach a "verdict." In this way, the sessions are guided by the concerns and interests of the participants, rather than solely determined by the researcher. NanoJuryUK (held in West Yorkshire over five weeks in the summer of 2005) proved to be a useful method to elicit public evaluations of nanotechnology—something that is scientifically complex, difficult to visualize, and difficult to represent psychologically.[50] Although participants initially struggled with the topic, its ultimate success suggests that it is a methodology that might conceivably lead to substantive public engagement with the social and ethical questions that geoengineering raises.

In addition to citizens' juries, upstream deliberative workshops have been trialled using members of the British and American public. Using the deliberative workshop format, quasi-representative groups of the public from the United Kingdom and the United States were convened to debate nanotechnology.[51] The groups discussed the risks and benefits of specific nanotechnology applications using a combination of World Café discussion sessions and written materials to draw on. Interestingly, a firm conclusion (echoing the findings of the DEEPEN project described earlier) was that the social trumped the technical in people's discussion of risk—that is, discussions focused predominantly on the social and ethical implications of nanotechnology, rather than questions of physical risk (despite the groups being provided with information about physical risks). A key question is whether such deliberative workshops will be an effective method of upstream engagement on geoengineering (where social and ethical questions are likely to be pertinent). They seem to provide a forum for precisely the type of nontechnical concerns that traditional risk assessment approaches to analysis struggle to capture.

Our argument is that the upstream public engagement tools that have been developed for studying nanotechnology may also be usefully applied to assess people's perceptions of the social and ethical implications of geoengineering. It will not be an easy challenge to meet. Relocating public debate about geoengineering to an earlier point in its development will not address the generic difficulties of public engagement—who should participate, the efficacy of different approaches, the clarification of aims and the need to ensure the results of any engagement exercise are taken on board by decision-makers, as well as the means for locating dialogue within existing modes of democratic and public representation. Equally, upstream engagement brings a range of unique issues relating to the design of participatory exercises. In the case of nanotechnologies, the very absence of products and easy everyday analogies through which people can interpret the science means they often struggle (initially at least) to get a grip on the topic. In turn, this means that engagement mechanisms require at least some level of information provision about the issue, raising the question of how this information is framed and presented by the dialogue organizers.

Many attempts at upstream public engagement suffer from two problems: a profound ambivalence on behalf of the public, and a general cynicism about whether the results of engagement exercises are taken seriously by decision-makers and stakeholders.[52] Decision-makers must be careful not to use upstream public engagement as an opportunity to "get in early" with pro-geoengineering public relations campaigns, but even more importantly, every effort must be made to make public engagement opportunities available to as many people (and as many different types of people) as possible.

The recent World Wide Views on Global Warming project represents an attempt to pursue public engagement on a global scale.[53] The project was a global citizen consultation that took place on September 26, 2009 in 38 countries, involving 4,400 citizens. Each deliberation included around 100 participants, who were selected to be demographically representative for the region. Participants discussed and debated views on the policy goals of the United Nations Climate Change Negotiations in Copenhagen. While 4,400 people still represent a tiny minority of the worldwide population, the project suggests that public participation projects need not (and should not) be restricted to the citizens of industrialized, Western nations.

Conclusion

Research into the technical feasibility and safety of geoengineering is poised to begin, with guarded interest from research funders, governments, and academic bodies in the United States and Europe. We have argued that it is essential that a program of social research and reflection be initiated as well, prior to the physical program. The deliberative techniques that have been trialled in research on nanotechnology offer potential opportunities for meaningful public engagement.[54] Even under conditions of high uncertainty that characterize emerging technologies such as geoengineering (something the philosophers Jerry Ravetz and Silvio Funtowicz have termed *post-normal science*),[55] upstream deliberative methods can play a critical role in allowing a broader range of voices to be heard and in extending the dialogue between experts and society.

But while it is relatively straightforward to elicit views and opinions from members of the public, ensuring that these views are given weight and legitimacy by decision-makers is a major undertaking. There is, therefore, a significant challenge for public engagement researchers and policy-makers to develop a genuinely partici-

ISTOCKPHOTO/KTSIMAGE

pative model of upstream public engagement around geoengineering that does more than simply move consultation processes to an earlier phase in the technology's development. Public engagement must be initiated before the scientific community begins to investigate the potential of geoengineering, precisely because the social and ethical questions that geoengineering raises will be much more difficult to address in a satisfactory way once large-scale research is underway. If experiments are to be conducted with geoengineering at the level required to adequately assess its impacts—that is, real-world experiments with the world's climate—the opportunity to engage the public in meaningful dialogue may have already passed. The need for upstream engagement on geoengineering is, therefore, pressing.

Encouragingly, the Royal Society report included a preliminary investigation of public attitudes towards geoengineering.[56] Focus groups composed of participants with different environmental beliefs and behaviors discussed possible risks, benefits, and uncertainties of different geoengineering technologies. Perceptions of geoengineering were generally negative, with concern over vested commercial interests, environmental impact, and transparency of regulation (this can be contrasted with general views about nanotechnology, which have tended to be broadly positive)[57]. However, there was also a suggestion that geoengineering proposals might galvanize (rather than distract from) mitigation strategies—several participants who were generally sceptical towards climate change perceived government investment in geoengineering research as a reason for increased personal engagement.

Of course, upstream engagement on geoengineering is not just about alerting the public to risks and dangers they might otherwise not be aware of; addressing the ethical and social questions that geoengineering raises may actually increase the likelihood of a technical program beginning. This is not because upstream engagement offers an early opportunity to allay fears, but because previous experience with biotechnology has suggested, for example, that failing to effectively engage the public led to GM food becoming an iconic topic for broader political debate and controversy.[58] Engagement exercises should not aim to stymie research or limit academic freedom, but to enrich societal debate and the decision-making process. A good example of this is a recent British dialogue with members of the public about the use of nanotechnologies in healthcare. As well as identifying positive and negative perceptions of the role of nanotechnologies in health, the process provided valuable input that aided the development of the research program.[59]

Upstream engagement with the public may also simply lead to neither acceptance nor rejection. Some recent studies of public attitudes towards nanotechnology have suggested that people with opposing views of science and technology tend to polarize the more they know about the risks and benefits of nanotechnology.[60] Different approaches to geoengineering may also raise different social and ethical issues—the question of international consent is arguably less pressing for localised sequestration methods than it is for the use of stratospheric aerosols.[61] But whatever the outcome of involving the public in a discourse about the questions that geoengineering raises, beginning this process at the earliest possible stage seems essential. Genuinely upstream research and engagement asks not only what the impacts of a particular new program of technological innovation will be, but whether that program is desirable in the first place.

These concerns make clear that upstream engagement is unlikely to be a panacea for deeply ingrained tensions between science and broader society. In fact, the significant practical challenges of implementing an ambitious program of global upstream engagement on geoengineering highlight the issues associated with global risk assessment, engagement, and governance more generally. As demonstrated by analyses of the international risk governance of nanotechnology, increasing technological globalization is not always matched by a corresponding convergence of risk assessment and governance.[62] Geoengineering proposals would seem to speak directly to the environmental campaigner George Monbiot's concern that everything has been globalized—except our consent.[63] Any legitimate process of public engagement on geoengineering will need to fight hard to reach as broad a group of citizens as possible (possibly including multistage and multimethod approaches—see Sidebar, "Some Approaches to Upstream Engagement"). Initiating an international program of social and ethical research before making a decision about whether to commence a technical program on geoegineering is one way to ensure that this goal is achieved.

Engagement exercises should not aim to stymie research or limit academic freedom, but to enrich societal debate and the decision-making process.

In assessing the potential for upstream engagement in light of lessons learned from the debates over GM food, Sheila Jasanoff has suggested that the "hidden normative presumptions" of science needed to be revealed in order for genuinely participatory public engagement to ensue.[64] By being willing to subject the central tenet of post-Enlightenment science (a firm conviction in the positive value of scientific and technological progress) to an open-ended debate involving a broad range of members of the public, Jasanoff proposes that upstream engagement could mitigate against a division between science and society. It is our hope that a comprehensive strategy of upstream public engagement on geoengineering can achieve a similar goal.

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