

# Research Articles

## Solar Geoengineering and Democracy

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*Joshua B. Horton, Jesse L. Reynolds, Holly Jean Buck,  
Daniel Callies, Stefan Schäfer, David W. Keith,  
and Steve Rayner\**

### Abstract

Some scientists suggest that it might be possible to reflect a portion of incoming sunlight back into space to reduce climate change and its impacts. Others argue that such solar radiation management (SRM) geoengineering is inherently incompatible with democracy. In this article, we reject this incompatibility argument. First, we counterargue that technologies such as SRM lack innate political characteristics and predetermined social effects, and that democracy need not be deliberative to serve as a standard for governance. We then rebut each of the argument's core claims, countering that (1) democratic institutions are sufficiently resilient to manage SRM, (2) opting out of governance decisions is not a fundamental democratic right, (3) SRM may not require an undue degree of technocracy, and (4) its implementation may not concentrate power and promote authoritarianism. Although we reject the incompatibility argument, we do not argue that SRM is necessarily, or even likely to be, democratic in practice.

Some scientists suggest that it might be possible to moderate anthropogenic climate change and its impacts by reflecting a small portion of incoming sunlight back to space (McNutt et al. 2015; Shepherd et al. 2009). Researching such solar radiation management (SRM), also known as solar geoengineering, was largely taboo until recently. Current research suggests that SRM could partially counter climate change and associated impacts but would pose serious sociopolitical challenges and environmental risks.

One of the greatest challenges for proposed SRM methods—such as injecting minute particles into the upper atmosphere—concerns governance. SRM would have global effects, yet some versions appear to have such low direct implementation costs and to be so technically simple that some individual countries could implement it, at least in principle. Countries seeking to deploy might disagree over SRM implementation, including how strongly, how quickly,

\* We are grateful for the helpful comments of Toby Svoboda, Jane Flegal, three anonymous reviewers, the journal's editors, and especially Clare Heyward. This article originated at the 2016 Harvard University Summer Research Residency on Solar Geoengineering.

and when to intervene. Other countries might expect SRM to make them worse off, and some might object to the very notion of deliberate intervention in the global climate. Subsequent extreme weather events might be attributed to SRM. Under plausible scenarios, SRM could increase international tensions and possibly destabilize the international system. Hence, as Lloyd and Oppenheimer (2014, 50) write, “the purpose of SRM governance is not only to deter SRM deployment in the near term, but also to assure that any future consideration of SRM deployment adheres to normative criteria.”

Many observers have argued that the environmental and political implications of SRM thus point toward the need for global governance institutions, yet these in turn would have their own political implications at global, national, and local levels. Researchers have considered such effects in other areas of global environmental politics, such as carbon markets and forest conservation, where efforts at transboundary environmental management have led to unexpected and undesired outcomes. In these cases, they have largely focused on the political consequences of policies and institutions rather than on technologies per se.

In the case of SRM, however, some scholars have argued that the technology itself is inherently incompatible with democracy.<sup>1</sup> This argument has been influential in SRM debates and is increasingly manifest in broader conversations about global environmental governance (e.g., Eckersley 2017, 6). In this article, we reject the argument that SRM and democracy are necessarily incompatible. Although SRM, if developed, could conceivably be implemented in an authoritarian fashion, we contend that it could also, conceivably, be deployed on alternative political bases, including democratically. This possibility depends, among other things, on how one defines democracy. Importantly, our counterargument is *not* that SRM *would* be democratically governed but rather that SRM *could* develop along many political trajectories, including under both democracy and authoritarianism.

The most explicit statement of the view that SRM and democracy are incompatible is the article “Why Solar Radiation Management Geoengineering and Democracy Won’t Mix” by Szerszynski et al. (2013), which expands on arguments advanced by Macnaghten and Szerszynski (2013). Based on our reading of these two pieces as well as other contributions (including Hulme 2014; Owen 2014), we consider the argument that SRM is necessarily undemocratic—which we call the *incompatibility argument*—to be composed of four claims: SRM would stretch democratic institutions to the breaking point; it would preclude opting out, which is essential to democracy; it would require undue technocracy; and it would concentrate power and promote authoritarianism.<sup>2</sup> Importantly, while these claims are grounded in considerations of democracy at the national level, they are often extended to apply to global governance.

1. Some of this criticism applies generally to SRM, whereas some is directed toward one specific proposed SRM method: stratospheric aerosol injection. We believe that both the criticism and our counterargument are applicable to SRM as a whole.
2. Although Szerszynski et al. (2013) use four arguments, our scheme does not align with theirs.

In the following section, we show that the incompatibility argument depends on assumptions grounded in technological determinism and on a particularly deliberative understanding of democracy. Following this, we summarize and counter the main claims noted earlier. We end with a short conclusion.

## Determinism and Deliberation: Problematic Prerequisites

The argument that SRM is necessarily incompatible with democracy is flawed due to two core theoretical assumptions on which it is based: first, that a technology possesses inherent political attributes that predetermine how it enters into and reshapes social and political life, and second, that deliberative democracy offers the only valid standard of democracy. We consider each of these in turn.

Technological determinism permeates the incompatibility argument. For example, Szerszynski et al. (2013, 2811) argue that SRM is intrinsically political, “unfavourable to certain patterns of social relations, and favourable to others.” In their view, specific distributions of power and authority are inscribed into these technologies from the start. By making this assumption, proponents of this argument conclude that SRM *must* be undemocratic rather than compatible with multiple political configurations.

Many scholars from science and technology studies have argued that technologies are not politically neutral. This has led some to argue further, asserting that technologies are inherently political and are imbued with essential properties that give rise to fixed social and political effects. The incompatibility argument follows from this latter understanding (e.g., Winner 1980).

This approach has drawn criticism (e.g., Joerges 1999). For example, Latour, writing as Johnson (1988), has argued that a technology’s political life is contingent upon how human and nonhuman actors are networked with one another. Others hold that it results from design choices, while recognizing that these choices might ultimately become “locked in” (Collingridge 1982). Indeed, claims about a technology’s inevitable political consequences have repeatedly proven wrong. For example, early euphoria about the emancipatory potential of information and communication technologies is now rivaled by anxiety about the potential for surveillance and control that connectivity affords.

Clearly some of a technology’s political implications are the product of design choices, made within existing political, economic, and social structures. Thus these implications cannot be fully determined before design choices are made. It is conceivable that, given a particular distribution of power and interests, design choices are likely to go in one direction rather than another. However, a technology’s attributes are never fully fixed, even after it has been brought into physical existence, because how it is used and understood, as well as the technology itself, continually changes.

Although early assessments of SRM have suggested certain characteristics’ inevitability, evolving research has destabilized some of these conjectures. Social scientists have encouraged SRM researchers to confront their political and social

entanglements (Bellamy and Lezaun 2017) and have documented the articulation of, and contestation over, multiple meanings and framings of SRM among publics, suggesting its polyvalence at this stage (Burns et al. 2016). As Stilgoe (2016) argues, SRM governance stands to benefit from taking the technology's social-experimental nature seriously and avoiding deterministic frames.

Given emerging theoretical and empirical work, and in line with a non-deterministic perspective on technological politics, we argue that SRM's political future is yet to be written. If developed, SRM might be democratic, authoritarian, or something else. Its ultimate constitution is not inscribed in its (nonexistent) material substance. Instead, its configurations of power and authority would arise through the interplay of social and material forces that cannot be foreseen.

The second theoretical assumption of the argument that SRM is inherently undemocratic relates to how democracy is conceived. By "democracy," we mean a political system in which people are meaningfully involved in decision-making, either directly or indirectly via representatives. Furthermore, representative democracies have free and fair elections and guarantees of civil and political rights. Although we acknowledge that no universally accepted definition exists, we regard ours as broadly consistent with both political theory and common usage of the term (e.g., Dahl 1961; Held 2006).

In our view, which follows Heyward and Rayner (2016; see also Wong 2016, 182), the incompatibility argument is grounded in a specifically *deliberative* notion of democracy, which envisions independent communities in which citizens are highly engaged and actively involved in decision-making on an egalitarian basis (Leib 2004). This grounding is not explicit. Indeed, some proponents of the incompatibility argument emphasize their neutrality with respect to models of democracy. Yet we believe it is implicit in their repeated emphasis on the importance of deliberation, debate, engagement, consensus, and reflexivity.<sup>3</sup> In our view, the notion of democracy advanced by proponents of the incompatibility argument foregrounds attributes that characterize deliberative democracy, and this carries important implications for their political assessment of SRM.

Clearly no national system of democracy meets the stringent standards of community-wide engagement, participation, and consent integral to deliberative democracy. Rather, where democracy is practiced, participation requires substantial time, motivation, and knowledge, capacities that vary widely across publics. Factors such as wealth and power shape individuals' control over their own lives and their access to decision-making. In some democracies, differences in electoral districts mean that voters in districts with small populations wield disproportionate influence. Insofar as proponents of the incompatibility argument assume that

3. This is unsurprising given that many of the same researchers have been closely involved in developing and promoting the Responsible Research and Innovation (RRI) framework. RRI is organized around principles of anticipation, reflexivity, deliberation, and responsiveness, and it is pursued through a process of meaningful public and stakeholder engagement (Owen et al. 2013). So essential is deliberation to this approach that RRI has been dubbed "the inheritor of deliberative democracy" (Reber 2017).

the democratic standard to be met is deliberative in character, SRM (or any other sociotechnical system) will face substantial hurdles in achieving legitimacy.

Deliberative democracy has numerous normatively desirable aspects. Yet, there is no consensus on what features would characterize a deliberative democracy. Those who make the incompatibility argument list formal institutions as paradigmatic features of democracy, without specific reference to how these would further deliberation: “political pluralism, free and fair elections, equality before the law, protection of civil liberties, freedom of speech, sovereignty of national governments, ability to get redress for harm through the legal systems, a minimal level of human rights, and a functioning civil society” (Szerszynski et al. 2013, 2810). Such institutions, however, might not necessarily promote deliberation. Dryzek (2000), for instance, contrasts formal “liberal constitutionalist deliberative democracy” (i.e., that which is expressed through formal institutions) with “discursive democracy” in which agents promoting competing discourses generate public opinion that ultimately shapes government policy. For Dryzek (2000, 17–20), the latter constitutes a more “authentic” form of deliberative democracy compared to a liberal constitutionalism constrained by the demands of capital, institutional failings, systematic participatory exclusions, and so on. To the extent that proponents of the incompatibility argument emphasize the role of institutions and deemphasize communicative action, theorists like Dryzek may object that they are in effect shortchanging deliberation.

Democratic theorists might also accuse these scholars of shortchanging the *practice* of deliberative democracy insofar as they treat it more as a fixed destination than as an unfolding, historically contingent, and transformative activity. This is evident when those who argue for incompatibility evaluate the democraticness of SRM by comparing its supposedly fixed characteristics with an implicit (institutional) ideal type of deliberative democracy. This approach is most apparent in Szerszynski et al. (2013) but is also present in the other articulations of the incompatibility argument cited earlier. This treatment of (deliberative) democracy as a determinate outcome echoes the assumption of technological determinism discussed previously.

This may be contrasted with an assessment method focused on evaluating the (deliberative) democratic potential of a sociotechnical system such as SRM. Such an approach would seek to identify possible pathways toward democracy associated with particular technologies and practices. For instance, Eckersley (2004, 115) views deliberative democracy not as a defined end point but rather as

the process by which we learn of our dependence on others (and the environment) and the process by which we learn to recognize and respect differently situated others (including nonhuman others and future generations). It is the activity through which citizens consciously create a common life and a common future together.

In her pursuit of “ecological democracy,” Eckersley regards deliberative democracy as fundamentally a communicative process. By neglecting the process dimension

of (deliberative) democracy, those who argue that SRM and democracy are incompatible might inadvertently privilege one demanding, aspirational, yet ossified model of politics, while overlooking the possibility that building SRM governance could, through the kinds of public discourse necessary for SRM to achieve a social license to operate, ultimately *enhance* democracy (Davies 2010, 279).

Beyond issues specific to deliberative democracy, most of those who make the incompatibility argument also poorly distinguish between domestic and international politics. In analytical terms, this blurring ignores significant differences between politics *within* countries, where government ranges from democracy to authoritarianism, and politics *among* countries, characterized by the absence of central authority. In many international forums, countries with small populations have the same legal status as much larger nations. At the same time, wealthy and powerful ones exert disproportionate influence. In this sense, the international system is undemocratic in sometimes contradictory ways.

International politics is not devoid of rules, norms, and expectations and can be characterized as more or less democratic. But given the relative thinness of social relations at the international level, global democracy is not on the horizon (Scholte 2014). In this context, asserting that SRM would be undemocratic at the international level says little about its political attributes. Those institutions that do exist at the international level, whether one thinks of them as democratic or not, might be sufficient for political deliberation of, and decision-making on, SRM (Schäfer et al. 2014, 242).

Grounding the argument that SRM is incompatible with democracy on an implicit deliberative model is flawed insofar as global democracy, with or without SRM, is unlikely ever to meet the model's demanding standards (whether conceived in discursive, institutionalist, or some other terms). The valid comparison is not between a democratically imperfect world with SRM and a perfect ideal of democracy but between two worlds equally imperfect in democratic terms, one with and one without SRM. In this analysis, the key question is not whether SRM is (in)compatible with democracy but whether it can be developed and possibly implemented through a decision-making process that does not significantly diminish democratic legitimacy.

Assuming technological determinism and deliberative democracy, some assert that SRM *must be* "undemocratic." We contend that this logic is flawed, as manifest in the four key claims constituting the incompatibility argument.

### **Claim 1: SRM Would Stretch Democratic Institutions to the Breaking Point**

The first of these claims is that, due to the high stakes involved, interests supporting SRM would be so entrenched and disagreements so intractable that democratic norms, practices, and institutions would be unable to resolve fundamental differences. Weighed down and compromised by irresolvable conflicts, political

instability, and contested notions of the public good, democratic institutions would prove incapable of governing. This assertion is built on three subclaims.

The first subclaim is that SRM would inevitably “cause conflicts within existing institutions” (Szerszynski et al. 2013, 2811). Parties would disagree about whether and how to use it, who would conduct it, conditions for cessation, compensation provisions, claims of attribution, and prior consent. Some commentators have argued that because SRM would produce uneven regional climate effects, it would necessarily result in winners and losers. While the magnitude of this issue is currently unclear, even if SRM were to distribute gains and losses unequally, it would not differ fundamentally in this respect from conventional responses to climate change. Governing institutions decided in the Paris Agreement to try to limit warming to 2 degrees Celsius, or even 1.5 degrees. Achieving this would result in an unequal distribution of gains and losses when compared with higher, lower, or no warming targets. Similarly, SRM might be implemented to limit warming to 1.5 or 2 degrees, to reduce the rate of climate change, or to eliminate it as much as possible. Each of these objectives, if achieved, would have unequal impacts relative to other targets.

Those arguing for incompatibility have also asserted that attribution of cause and effect would be impossible with SRM, making liability and accountability for its effects impossible. Researchers have made progress in attributing specific events to anthropogenic climate change using probabilistic methods (Stott et al. 2016), and this knowledge could be extended to SRM (Horton et al. 2015, 225). There are also ways of dealing with compensation that avoid attribution, such as through compensation funds (Reynolds 2015; Wong et al. 2014).

Arguably, concerns about “deep uncertainty” animate some arguments regarding the incompatibility of democracy and SRM. Uncertainty is high, but that alone does not argue for the incompatibility of SRM and democracy without the further argument that uncertainty presents systematically larger challenges for democracy than for other forms of government. Proponents of the incompatibility argument have not articulated such a relative claim. Rather, they assert the generally uncontested fact that uncertainty is a challenge for decision-making and then (implicitly) assume that this presents a particular challenge for democracy.

From our perspective, while deep uncertainty presents challenges to democracy, democratic institutions are capable of handling them, for example, via innovative public engagement mechanisms (Bellamy and Lezaun 2017). Indeed, political theorists, such as Przeworski (1991), have argued that democracies are stable and resilient precisely because they “institutionalize uncertainty,” so that no party is permanently out of power and no policy is perpetually off the table.

The second subclaim is that the intentions behind SRM would be “plural and unstable,” bringing “prior democratic consent” into question (Szerszynski et al. 2013, 2812–2813). Macnaghten and Szerszynski (2013, 467) state that “whether or not a specific action such as releasing particles into the upper atmosphere counts as SRM geoengineering deployment, or as research, or even as mere pollution cannot be determined by a mere technical procedure, but only

by reference to intent.” This need not be the case, as SRM could be regulated without reference to intent by relying instead on the nature, location, and quantity of introduced material or the expected impact (Parson and Keith 2013). Alternatively, if such regulation were to refer to intent, it would not be novel. Democracies regularly regulate based on intent, for instance, regarding crime.

Beyond this, however, those who assert incompatibility make the more basic argument that because the intentions behind SRM implementation would be plural and unstable, prior democratic consent could be rendered invalid. For instance, if actors consented to SRM implementation with the goal of “shaving the peak” off global warming, but the objective was subsequently altered to fully offsetting climate change, then prior consent would be called into question. This scenario seems plausible, but it reflects a pattern common to many public policy decisions, about which little concern regarding democratic legitimacy is otherwise expressed. For example, the international regime to sustainably regulate whaling has evolved into one to end the practice (Bodansky 2009, 577). Unanimity of motive across space and time is not a necessary condition of democracy. To the contrary, democracy assumes that citizens’ interests are both variable and reconcilable through periodic elections. Recent controversies regarding same-sex marriage, abortion, and immigration all show that democratic institutions can reach decisions on such polarizing issues without imperiling underlying democratic systems.<sup>4</sup>

The third and final subclaim is that powerful “economic interests” would co-opt SRM.<sup>5</sup> According to this view, political and economic actors would exploit SRM to serve their own interests rather than the public good (Szerszynski et al. 2013, 2814). However, of the potential tools for managing climate change risk, SRM has perhaps the smallest opportunity for direct private economic gain. Estimates for its direct implementation costs are about US\$ 5–50 billion annually, much smaller in comparison with typical projections associated with optimal levels of mitigation, adaptation, and carbon dioxide removal technologies.

A more valid concern is that SRM technology might be used by interests who rely on continued greenhouse gas emissions to weaken mitigation efforts. On one hand, it would be naive to assume that interests integral to the carbon economy would not seize on SRM in this way. They have already done so (although only partially and unsuccessfully) in the case of carbon capture and storage (Vormedal 2008). On the other hand, they have not yet advanced SRM, just as they have not embraced climate adaptation, which could also be used to weaken mitigation efforts. It remains unclear what approach, if any, they might take with respect to SRM. Ultimately, the potential for fossil fuel and related industries to co-opt the SRM agenda might, or might not, present a serious challenge. At the same time, other instances of private interests advocating for policies that benefit them are not considered incompatible with democracy (although particular means of doing

4. The issue of motivation is also intimately entangled with ideas of consent, which we address in the next section.

5. See also Stirling (2014, 21), who asserts that SRM is “‘regressive’ in the sense of being aligned with entrenched existing concentrations of power extending out from the energy sector.”



so might be). Indeed, many political theorists regard pluralism—according to which government mediates among a competing array of interest groups and other private actors—as essential to democracy (Dahl 1961).

## **Claim 2: SRM Would Preclude Opting Out, Which Is Essential to Democracy**

The second key claim of the incompatibility argument is that the global scale of SRM's effects means that actors and communities would lose their right to "opt out" of collective decisions when they conflict with strongly felt preferences and that this right is a core tenet of democracy. Macnaghten and Szerszynski (2013, 473) state this most clearly:

While plausibly able to accommodate diverse views into the formulation of [SRM's] use, once deployed, there remains little opportunity for opt-out or for the accommodation of diverse perspectives. ... Following deployment it could only be controlled centrally and on a planetary scale.

From this, they conclude that SRM has an "anti-democratic constitution" and is "incompatib[le] with liberal democracy." Likewise, for Hulme (2014, 81–82), the technical characteristics of SRM preclude opting out, therefore its governance can never be satisfactory and it should not be pursued. The implication is that compatibility with democracy requires an ability to opt out of the effects of public decisions regarding technologies.

The assertion that democracy entails such a right to opt out is a specific form of the assertion that democracy entails a right to opt out of the effects of any government policy. Proponents of this view appear to believe that democracy must allow people to shield themselves from the effects of public policies to which they object.

Put bluntly, this is simply not how democracy, or any government, works (Heyward and Rayner 2016; see also Hansson 2006; Morrow et al. 2013, 148–149; Wong 2016). It is an axiom of social contract theory that the establishment of a democratic state requires the consent of the governed. It is equally axiomatic, however, that once a democracy is operating, citizens should comply with the law so long as it was developed democratically and basic rights are protected. For example, Rousseau (1998, 108) argued in *The Social Contract* that

there is but one law which by its nature requires unanimous consent, that is, the social compact.... When the State is established, consent lies in residence; to dwell in the territory is to submit to the sovereignty.... The citizen consents to all the laws, even to those passed in spite of him, and even to those that punish him when he dares to violate any of them.

Although exit rights, entitling those who wish to opt out of one jurisdiction to move to another, might exist, residents of a country may not choose to opt out of individual policy decisions.

In fact, it is the *absence* of a right to opt out that gives governments—including democracies—the capacity to address problems that self-organizing individuals cannot. Suppose that a policy benefits all or most people but requires some contributions from them. If people could opt out, then each person might do so with the hope of free riding on others' contributions. Furthermore, few actual policies benefit everyone. For example, suppose a factory is prohibited from using cheap but polluting production processes. The pertinent regulation might lead to a net improvement in people's well-being, but the factory's owners (and perhaps its workers and consumers of its products) would suffer. If the owners could opt out of this regulation, then the harmful pollution would continue. Ultimately, a right of opt out from collective decision-making would give each person a veto over many, if not all, public policy decisions and undermine the stability of social relations on which polities, democratic or otherwise, depend (Rawls 1999, 398).

Rather than the Lockean concept of consent of the governed, those who make the incompatibility argument appear to have in mind something closer to prior informed consent, a procedure relating to participation in hazardous activities, such as medical research. Szerszynski et al. (2013), for example, use terms such as "prior democratic consent" (2813) and "informed consent" (2814). The standards for prior informed consent are more demanding than for democratic consent more generally, and SRM might or might not meet the former standards. However, democracy does not require prior informed consent, which in practice is used only under a narrow set of circumstances.

Democratic forms of government are also characterized by the boundaries they should not cross, in particular, fundamental rights. Violations of these can justify protest or civil disobedience, through which citizens in effect seek to "opt out" of democratic overreach. Yet it is unclear how SRM might violate fundamental rights to a degree that exceeds what occurs routinely in tax collection, military conscription, and eminent domain (i.e., expropriation), all of which are viewed as compatible with democracy.

The fact that SRM would have global impacts does not undermine our counterargument. To the extent that institutions of global governance might reflect democratic values at the international level (Buchanan and Keohane 2006), the ability to opt out of the effects of global public policies is not a necessary condition, for similar reasons of efficacy and stability. Asserting such a right to opt out would both undermine the purposes of global governance, that is, managing and resolving transnational problems (Dingwerth and Pattberg 2006), and undercut the institutional and policy stability on which successful global governance depends.

While the absence of an ability to opt out of decisions about SRM does not run counter to democracy, the same cannot be said of the potential for unilateral deployment. The possibility that one state (or a handful of them) might

implement SRM against the wishes of the international community represents a threat to democracy insofar as people and states might be denied meaningful involvement in decisions that significantly affect them. Yet this feature is hardly unique to SRM. Indeed, restraints on unilateral action constitute much of the substance of democratic politics domestically and globally, from national pollution controls to international trade law, and the technologies and activities regulated by such restraints are not regarded as somehow incompatible with democracy.

### **Claim 3: SRM Would Require Undue Technocracy**

The third claim of the incompatibility argument is that, because decisions about implementing and maintaining SRM would be highly technical, SRM would require undue technocratic governance in which a narrow set of expert elites would determine climatic conditions (Hulme 2014; McLaren 2016; Szerszynski et al. 2013). Such technocracy, proponents claim, would be undemocratic. Szerszynski et al. (2013, 2812), for instance, assert that SRM

could generate a closed and restricted set of knowledge networks, highly dependent on top-down expertise and with little space for dissident science or alternative perspectives. Furthermore, the complexities that would accompany the climate modelling would ensure that expertise would remain minimally distributed and personally remote. The idioms surrounding discussion over its use would remain, at least at first, expert led and opaque.

Such critics argue that by virtue of its complex, technical nature, decision-making about SRM would privilege experts at the cost of public input into decisions regarding SRM. The inaccessibility of technical language and a lack of specialized training would place laypeople and even popular representatives in positions of dependence and potential vulnerability vis-à-vis expert managers. Self-determination would be supplanted by technocratic fiat and, with it, a cornerstone of democratic politics.

In response, we argue first that SRM might not require governance that is more technocratic than that of other existing endeavors and second that such existing arrangements can be compatible with democracy.

To be clear, any responsible implementation or large-scale outdoor experiments of SRM would indeed require expert input, guidance, and decision-making. However, this fact alone does not imply that decision-making regarding SRM must be technocratic in a way that excessively wrests authority from democratic institutions. When it comes to nonexpert involvement in technical decision-making, there is substantial evidence that opening up risk assessment to democratic debate is good for science and innovation (Sarewitz 2015). With regard to SRM, empirical research indicates that lay publics can sufficiently

understand and engage with technical issues (Pidgeon et al. 2013; Wibeck et al. 2015). There is no a priori reason to assume that nonexperts could not be involved in SRM decision-making.

Societies, including democratic ones, already engage in and govern a number of activities that rely on technical experts for decision-making (Keith 2017). In these arrangements, the nature of expert accountability varies. There are at least three archetypal technocratic arrangements, each of which contains mechanisms to facilitate and/or enhance democratic accountability and legitimacy. First, experts can function as advisers, but public actors who are usually democratically accountable make decisions. Such decisions are sometimes made with public input obtained through formalized processes and are subject to other checks, such as judicial review. For example, in the US, independent expert-led Base Realignment and Closure commissions have recommended which military bases to close since the end of the Cold War, but Congress has made the final decisions. Second, in other instances, appointed experts make decisions but are subject to democratic oversight and are accountable to the public, at least indirectly, and to judicial review. For example, environmental agencies—whose leadership is appointed by and serves at the pleasure of elected leaders—set limits for pollutants. Finally, in some cases, technical experts who are not directly accountable, or only tenuously so, are responsible for decision-making, frequently to prevent interest groups from influencing outcomes for their own benefit. Even these expert decision-makers are ultimately accountable, however. They can be appointed by elected representatives, who also often can renew (or not) their terms, and sometimes remove them. At the very least, their actions and legacies are subject to public debate. An example is constitutional courts, whose delegated authority is sometimes criticized as politically problematic but rarely as inherently incompatible with democracy.

Decisions regarding SRM could conceivably assume any of these forms. Experts' role in governing SRM could be limited to that of expert advisers, with substantive decisions left in the hands of some configuration of traditional representatives or diplomatic representatives thereof. Alternatively, the experts who make decisions could be accountable to democratic leaders. Or substantially empowered, highly insulated experts could undertake SRM decision-making. Ultimately, if we can conceive of decision-making processes for SRM that contain robust elements of democratic accountability, then such decision-making need not necessarily be incompatible with democracy, even if these processes are somewhat technocratic.

#### **Claim 4: SRM Would Concentrate Power and Promote Authoritarianism**

The final key claim of the incompatibility argument is that SRM implementation and maintenance would require a truly global environmental management system, and enforcing compliance with its directives would necessitate the accumulation of power in centralized global institutions in a way that would favor the emergence of

authoritarianism.<sup>6</sup> Such a system would be at odds with democratic constraints on excessive concentrations of power. As Szerszynski et al. (2013, 2812) put it,

the social constitution of SRM geoengineering through stratospheric aerosol injection would be strongly compatible with a centralised, autocratic, command-and-control world-governing structure, in tension with the current, broadly Westphalian, international system based on national self-determination.

Because implementation would be planetary in scale, decisions would need to be planetary as well, leaving little room for dissent. In some versions of this claim, decisions rely on emergency rationales (Hamilton 2013, 104, 134; Hulme 2014, 77).

On closer examination, this claim is imprecise, confused, and presumptive. The claim is imprecise insofar as it is not always clear whether the imagined authoritarianism would be required at the national level, the international level, or both. In principle, exclusively authoritarian sovereign states could make collective global governance decisions on a democratic intergovernmental basis. Equally, one hegemonic democratic state could impose its will on less powerful democracies in a coercive manner.

The claim is confused about what constitutes authoritarianism. Proponents of the incompatibility argument often seem to equate authoritarianism with centralized decision-making. At the extreme, this is true: a single decision maker wielding absolute power is by definition an autocrat. Yet there is a wide spectrum of political centralization, including *within* democracies. Political scientists, for example, distinguish between relatively centralized majoritarian models of democracy and relatively decentralized consensus models, with a number of hybrids occupying the space between (Lijphart 1984). In short, some degree of hierarchy and centralization characterizes every polity. Whether a hierarchical or centralized political system qualifies as authoritarian depends on additional factors, such as the impartiality of rules, accountability, transparency, access, modes of participation, and freedom of expression, upon which those who allege SRM's incompatibility with democracy do not elaborate.

Finally, the claim is presumptive in assuming that SRM decision-making would be centralized. Certainly a vision of centralized SRM has dominated the discourse about it, but SRM could be implemented by numerous, loosely coordinated actors with no central control, each contributing to a global result. While such a distributed form of SRM has not been widely discussed, it appears possible and runs counter to the concentrated power constitutive of authoritarianism.

This worry about authoritarianism might have been born out of the specific implementation scenarios sometimes considered by early SRM researchers

6. By authoritarianism, we mean a political system characterized by a hierarchical power structure with little opportunity for popular participation in decision-making.

(Heyward and Rayner 2016). Talk of a so-called climate emergency in which SRM would have to be deployed “quickly” might have conjured up thoughts of authoritarian governments declaring martial law, usurping and centralizing all decision-making power to avert a crisis (Horton 2015). Such an emergency response could pose a serious threat to democratic norms and practices. However, in recent years, researchers have moved away from such emergency framing toward alternative scenarios, for example, slowly ramping up SRM to shave off peak climate risks (Keith and MacMartin 2015).

More broadly, and contradicting the claim that SRM would require authoritarianism, the need for centralized decision-making does not automatically entail authoritarian control. Coordination and cooperation can be achieved in a multiplicity of ways that do not involve authoritarianism, as multiple domestic and international regimes show. The US Clean Air Act is an example at the domestic level. While acceptable levels of air quality are decided centrally at the federal level, implementation is conducted at the state level. Internationally, the Montreal Protocol requires all parties to reduce their chlorofluorocarbon consumption and production, a decision that has positive environmental effects but initially at least had substantial economic consequences. All countries of the world, many of them democracies, agreed upon the Protocol. SRM implementation could have a similar trajectory, allowing for periodic assessment and input from various parties pertaining to the experienced effects of implementation.

It is entirely possible that SRM could be controlled along authoritarian lines in the future. Yet this possibility exists with many technologies and other contemporary phenomena for which authoritarian control is not a foregone conclusion. We contend that multiple states can and do cooperate in managing global issues and that democracies can and do maintain their democratic characters even when making decisions with high stakes, high complexity, and deep uncertainty.

## Conclusions

The argument that SRM is necessarily incompatible with democracy is a prominent one in discussions of SRM. We reject this argument and the four key claims on which it is based. Contrary to what some observers contend, democratic institutions are resilient, and SRM would not necessarily stretch them to the breaking point. A broad ability to opt out of collective decisions, far from being essential to democracy, is likely to undermine it. SRM might not require undue technocracy, and its implementation might not promote authoritarianism. Fundamentally, the argument that SRM and democracy are incompatible is based on problematic assumptions of technological determinism, which is misguided in its neglect of social contingency, and deliberative democracy, which is an excessively high standard for contemporary politics.

Although we do not assert that SRM would likely be democratic in practice, we can envision a variety of SRM governance institutions that could promote debate and reach agreement in ways widely regarded as democratic. Such institutions at the international or global level may be less democratic than those at national or local levels, yet they might still embody democratic principles in ways that are meaningful to states and their citizens (Buchanan and Keohane 2006).

We share with proponents of the incompatibility argument a sense of urgent concern about the legitimacy of governance for SRM, but we hold that governance institutions—not technologies—are the proper objects of political assessment. Indeed, SRM poses substantial challenges for global governance. We do not dismiss commentators' specific concerns about potential conflict, consent, technocracy, and authoritarianism. We have also noted problems related to possible unilateral and/or emergency implementations. Other challenges include, *inter alia*, the possible weakening of mitigation efforts in response to SRM, compensation for harm, long-term management requirements, and program termination. How global governance norms, rules, and institutions could ultimately be developed to address these issues is uncertain and contested, but we strongly believe that any governance institutions that are developed should be aligned with democratic principles.

Some preliminary work on governance reflects this concern. For example, a group of scholars (including one of the present authors) developed a set of five general principles for geoengineering governance (Rayner et al. 2013). Each of these "Oxford principles" could help make democratic governance of SRM more likely. Two of them in particular—"public participation in geoengineering decision-making" and "disclosure of geoengineering research and open publication of results"—are clearly essential to democratic governance. The principles have been generally well received by diverse actors in the geoengineering discourse. Following such early efforts, a more robust literature on possible governance arrangements for SRM has emerged (Lloyd and Oppenheimer 2014; Parson 2017; Virgoe 2009; Zürn and Schäfer 2013). Up to now, however, scholars have not specifically addressed the degree to which more detailed governance proposals meet democratic criteria. We advocate more research on this critical question, without assuming answers *a priori*.

**Joshua B. Horton** is research director of geoengineering at the Harvard Kennedy School's Belfer Center for Science and International Affairs and also manages the Weatherhead Center for International Affairs Initiative on Climate Engineering. His research encompasses the politics, policy, and governance of solar geoengineering, with a current focus on compensation for harms arising from possible future deployment of the technology. From 2013 to 2016, Dr. Horton was a post-doctoral research fellow in the Belfer Center's Science, Technology, and Public Policy Program. He obtained a PhD in political science from Johns Hopkins University in 2007, where he specialized in international relations.

**Jesse Reynolds** is an assistant professor at the Utrecht Center for Water, Oceans, and Sustainability Law, Utrecht University, the Netherlands. He will soon be an Emmett/Frankel Fellow in Environmental Law and Policy at the University of California, Los Angeles, School of Law. Reynolds's monograph *The Governance of Solar Geoengineering* is forthcoming from Cambridge University Press. Dr. Reynolds obtained his PhD in international public law from Tilburg University (in part as Fulbright Fellow) and his master's in environmental policy from the University of California, Berkeley (as a US Environmental Protection Agency Science to Achieve Results Graduate Fellow).

**Holly Jean Buck** is a postdoctoral fellow at the Institute of the Environment and Sustainability at the University of California, Los Angeles. She's interested in how communities can be involved in the design of emerging environmental technologies. She works at the interface of environmental sociology and science and technology studies, with a PhD in development sociology from Cornell University. Her diverse research interests include agroecology and carbon farming, new energy technologies, artificial intelligence, and the restoration of California's Salton Sea. At present, she is studying the socio-political feasibility of using solar geoengineering to scale up carbon removal.

**Daniel Edward Callies** obtained his PhD from Goethe University Frankfurt, where he is a postdoctoral scholar at the DFG-funded Excellence Cluster "Normative Orders." His research focuses on normative and applied ethics, political philosophy, and climate justice. From 2016 to 2017, he was a predoctoral research fellow at Harvard's Kennedy School of Government in the Science, Technology, and Public Policy Program, and in 2017, he was the Bernheim Postdoctoral Fellow in Social Responsibility at the Université catholique de Louvain, Belgium. Before coming to Europe, he studied at San Diego State University, where he obtained both his BA (2008) and MA (2012) in philosophy.

**Stefan Schäfer** leads a research group at the Institute for Advanced Sustainability Studies in Potsdam, Germany, and is a visiting fellow in the Science, Technology, and Society Program at Harvard University. He is also an associate fellow at the Institute for Science, Innovation, and Society of the University of Oxford, where he was an Oxford Martin Visiting Fellow in 2017. Stefan was a guest researcher at the Social Science Research Center Berlin from 2009 to 2012 and has spent research stays at University College London (2013) and Harvard University (2015, 2016). He holds a doctorate in political science from Freie Universität Berlin.

**David Keith** has worked near the interface between climate science, energy technology, and public policy for twenty-five years. Best known for his work on the science, technology, and public policy of solar geoengineering, David



led the development of Harvard's Solar Geoengineering Research Program. He took first prize in Canada's national physics prize exam, won MIT's prize for excellence in experimental physics, and was one of *TIME* magazine's Heroes of the Environment. David is a professor at the Harvard School of Engineering and Applied Sciences and Harvard Kennedy School and founder of Carbon Engineering, a company developing technology to capture carbon dioxide from ambient air.

**Steve Rayner** is James Martin Professor of Science at Oxford University, where he codirects the Oxford Geoengineering Programme. He has served on various US, UK, and international bodies addressing science, technology, and the environment, including the Intergovernmental Panel on Climate Change, Britain's Royal Commission on Environmental Pollution, and the Royal Society's Working Group on Climate Geoengineering. In 2012–2014, he directed the UK ESRC's Climate Geoengineering Governance Project (<http://geoengineering-governance-research.org>). He is coeditor of the four-volume *Human Choice and Climate Change* (Battelle Press, 1998), *The Hartwell Approach to Climate Policy* (Earthscan, 2014), and *Institutional Capacity for Climate Change Response* (Routledge, 2017).

## References

- Bellamy, Rob, and Javier Lezaun. 2017. Crafting a Public for Geoengineering. *Public Understanding of Science* 26 (4): 402–417.
- Bodansky, Daniel. 2009. Is There an International Environmental Constitution? *Indiana Journal of Global Legal Studies* 16 (2): 565–584.
- Buchanan, Allen, and Robert O. Keohane. 2006. The Legitimacy of Global Governance Institutions. *Ethics and International Affairs* 20 (4): 405–437.
- Burns, Elizabeth T., Jane A. Flegal, David W. Keith, Aseem Mahajan, Dustin Tingley, and Gernot Wagner. 2016. What Do People Think When They Think about Solar Geoengineering? A Review of Empirical Social Science Literature, and Prospects for Future Research. *Earth's Future* 4 (11): 536–542.
- Collingridge, David. 1982. *The Social Control of Technology*. London: Pinter.
- Dahl, Robert A. 1961. *Who Governs? Democracy and Power in an American City*. New Haven, CT: Yale University Press.
- Davies, Gareth. 2010. Framing the Social, Political, and Environmental Risks and Benefits of Geoengineering: Balancing the Hard-to-Imagine Against the Hard-to-Measure. *Tulsa Law Review* 46 (2): 261–282.
- Dingwerth, Klaus, and Philipp Pattberg. 2006. Global Governance as a Perspective on World Politics. *Global Governance: A Review of Multilateralism and International Organizations* 12 (2): 185–203.
- Dryzek, John S. 2000. *Deliberative Democracy and Beyond: Liberals, Critics, Contestations*. New York: Oxford University Press.
- Eckersley, Robyn. 2004. *The Green State: Rethinking Democracy and Sovereignty*. Cambridge, MA: MIT Press.
- Eckersley, Robyn. 2017. Geopolitical Democracy in the Anthropocene. *Political Studies* 65 (4): 983–999.

- Hamilton, Clive. 2013. *Earthmasters: Playing God with the Climate*. Crows Nest, Australia: Allen and Unwin.
- Hansson, Sven Ove. 2006. Informed Consent out of Context. *Journal of Business Ethics* 63 (2): 149–154.
- Held, David. 2006. *Models of Democracy*. Cambridge, UK: Polity.
- Heyward, Clare, and Steve Rayner. 2016. Uneasy Expertise: Geoengineering, Social Science, and Democracy in the Anthropocene. In *Policy Legitimacy, Science and Political Authority: Knowledge and Action in Liberal Democracies*, edited by Michael Heazle and John Kane, 101–121. London: Routledge.
- Horton, Joshua B. 2015. The Emergency Framing of Solar Geoengineering: Time for a Different Approach. *The Anthropocene Review* 2 (2): 147–151.
- Horton, Joshua B., Andrew Parker, and David Keith. 2015. Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities. *New York University Environmental Law Journal* 22 (3): 225–273.
- Hulme, Mike. 2014. *Can Science Fix Climate Change? A Case against Climate Engineering*. Cambridge: Polity.
- Joerges, Bernward. 1999. Do Politics Have Artefacts? *Social Studies of Science* 29 (3): 411–431.
- Johnson, Jim. 1988. Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer. *Social Problems* 35 (3): 298–310.
- Keith, David. 2017. Toward a Responsible Solar Geoengineering Research Program. *Issues in Science and Technology* 33 (3): 71–77.
- Keith, David W., and Douglas G. MacMartin. 2015. A Temporary, Moderate and Responsive Scenario for Solar Geoengineering. *Nature Climate Change* 5: 201–206.
- Leib, Ethan J. 2004. *Deliberative Democracy in America: A Proposal for a Popular Branch of Government*. University Park, PA: Penn State University Press.
- Lijphart, Arend. 1984. *Democracies: Patterns of Majoritarian and Consensus Government in Twenty-One Countries*. New Haven, CT: Yale University Press.
- Lloyd, Ian D., and Michael Oppenheimer. 2014. On the Design of an International Governance Framework for Geoengineering. *Global Environmental Politics* 14 (2): 45–63.
- Macnaghten, Phil, and Bronisław Szerszynski. 2013. Living the Global Social Experiment: An Analysis of Public Discourse on Solar Radiation Management and Its Implications for Governance. *Global Environmental Change* 23 (2): 465–474.
- McLaren, Duncan. 2016. Framing Out Justice: The Post-politics of Climate Engineering Discourses. In *Climate Justice and Geoengineering: Ethics and Policy in the Atmospheric Anthropocene*, edited by Christopher J. Preston, 139–160. Lanham, MD: Rowman and Littlefield.
- McNutt, Marcia K., Waleed Abdalati, Ken Caldeira, Scott C. Doney, Paul G. Falkowski, Steve Fetter, James R. Fleming, Steven P. Hamburg, M. Granger Morgan, Joyce E. Penner, Raymond T. Pierrehumbert, Philip J. Rasch, Lynn M. Russell, John T. Snow, David W. Titley, and Jennifer Wilcox. 2015. *Climate Intervention: Reflecting Sunlight to Cool Earth*. Washington, DC: National Academies Press.
- Morrow, David R., Robert E. Kopp, and Michael Oppenheimer. 2013. Political Legitimacy in Decisions about Experiments in Solar Radiation Management. In *Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks*, edited by Wil C. G. Burns and Andrew L. Strauss, 146–167. Cambridge, UK: Cambridge University Press.

- Owen, Richard. 2014. Solar Radiation Management and the Governance of Hubris. In *Geoengineering of the Climate System*, edited by R. E. Hester and R. M. Harrison, 212–248. Cambridge, UK: Royal Society of Chemistry.
- Owen, Richard, Jack Stilgoe, Phil McNaghten, Mike Gorman, Erik Fisher, and Dave Guston. 2013. A Framework for Responsible Innovation. In *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, edited by Richard Owen, John Bessant, and Maggy Heintz, 27–50. New York: John Wiley.
- Parson, Edward A. 2017. Climate Policymakers and Assessments Must Get Serious about Climate Engineering. *Proceedings of the National Academy of Sciences of the United States of America* 114 (35): 9227–9230.
- Parson, Edward A., and David W. Keith. 2013. End the Deadlock on Governance of Geoengineering Research. *Science* 339 (6125): 1278–1279.
- Pidgeon, Nick, Karen Parkhill, Adam Corner, and Naomi Vaughan. 2013. Deliberating Stratospheric Aerosols for Climate Geoengineering and the SPICE Project. *Nature Climate Change* 3 (5): 451–457.
- Przeworski, Adam. 1991. *Democracy and the Market: Political and Economic Reforms in Eastern Europe and Latin America*. Cambridge, UK: Cambridge University Press.
- Rawls, John. 1999. *A Theory of Justice*. Cambridge, MA: Belknap Press.
- Rayner, Steve, Clare Heyward, Tim Kruger, Nick Pidgeon, Catherine Redgwell, and Julian Savulescu. 2013. The Oxford Principles. *Climatic Change* 121 (3): 499–512.
- Reber, Bernard. 2017. RRI as the Inheritor of Deliberative Democracy and the Precautionary Principle. *Journal of Responsible Innovation* 5 (1): 38–64.
- Reynolds, Jesse. 2015. An Economic Analysis of Liability and Compensation for Harm from Large-Scale Solar Climate Engineering Field Research. *Climate Law* 5 (2–4): 182–209.
- Rousseau, Jean-Jacques. 1998. *The Social Contract, or Principles of Political Right*. Hertfordshire, UK: Wordsworth Editions.
- Sarewitz, Daniel. 2015. CRISPR: Science Can't Solve It. *Nature* 522 (7557): 413–414.
- Schäfer, Stefan, Harald Stelzer, Achim Maas, and Mark Lawrence. 2014. Earth's Future in the Anthropocene: Technological Interventions between Piecemeal and Utopian Social Engineering. *Earth's Future* 2 (4): 239–243.
- Scholte, Jan Aart. 2014. Reinventing Global Democracy. *European Journal of International Relations* 20 (1): 3–28.
- Shepherd, John, Ken Caldeira, Joanna Haigh, David Keith, Brian Launder, Georgiina Mace, Gordon MacKerron, John Pyle, Steve Rayner, Catherine Redgwell, and Andrew Watson. 2009. *Geoengineering the Climate: Science, Governance and Uncertainty*. London: Royal Society.
- Stilgoe, Jack. 2016. Geoengineering as Collective Experimentation. *Science and Engineering Ethics* 22 (3): 851–869.
- Stirling, Andy. 2014. Emancipating Transformations: From Controlling “the Transition” to Culturing Plural Radical Progress. CGG Working Paper 12. Available at <http://www.geoengineering-governance-research.org/cgg-working-papers.php>, accessed May 24, 2018.
- Stott, Peter A., Nikolaos Christidis, Friederike E. L. Otto, Ying Sun, Jean-Paul Vanderlinden, Geert Jan van Oldenborgh, Robert Vautard, Hans von Storch, Peter Walton, Pascal Yiou, and Francis W. Zwiers. 2016. Attribution of Extreme Weather and Climate-Related Events. *WIREs Climate Change* 7 (1): 23–41.

- Szerszynski, Bronisław, Matthew Kearnes, Phil Macnaghten, Richard Owen, and Jack Stilgoe. 2013. Why Solar Radiation Management Geoengineering and Democracy Won't Mix. *Environment and Planning A* 45 (12): 2809–2816.
- Virgoe, John. 2009. International Governance of a Possible Geoengineering Intervention to Combat Climate Change. *Climatic Change* 95 (1): 103–119.
- Vormedal, Irja. 2008. The Influence of Business and Industry NGOs in the Negotiation of the Kyoto Mechanisms: The Case of Carbon Capture and Storage in the CDM. *Global Environmental Politics* 8 (4): 36–65.
- Wibeck, Victoria, Anders Hansson, and Jonas Anshelm. 2015. Questioning the Technological Fix to Climate Change: Lay Sense-making of Geoengineering in Sweden. *Energy Research and Social Science* 7: 23–30.
- Winner, Langdon. 1980. Do Artifacts Have Politics? *Daedalus* 109 (1): 121–136.
- Wong, Pak-Hang. 2016. Consenting to Geoengineering. *Philosophy and Technology* 26 (2): 173–188.
- Wong, Pak-Hang, Tom Douglas and Julian Savulescu. 2014. Compensation for Geoengineering Harms and No-Fault Climate Change Compensation. CGG Working Paper 8. Available online at: <http://www.geoengineering-governance-research.org/cgg-working-papers.php>, accessed May 24, 2018.
- Zürn, Michael, and Stefan Schäfer. 2013. The Paradox of Climate Engineering. *Global Policy* 4 (3): 266–277.