"It's Not the Climate, Stupid": Exploring Nonideal Scenarios for Solar Geoengineering Development

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"Solar geoengineering" refers to a group of speculative techniques for intervening in the climate system that could reduce the effects and impacts of climate change. The most widely considered of these potential approaches include proposals to reflect incoming sunlight by spraying reflective particles into the stratosphere, brightening marine clouds, and deploying mirrors in space.[1] Proposed real-world experiments have proved controversial, and efforts to establish governance regarding the possible deployment of such technologies are contested and polarizing.[2] Existing knowledge about solar geoengineering therefore remains largely based on idealized earth-system modeling and examines a limited set of deployment scenarios. This work broadly presumes that solar geoengineering would only be used for the purpose of ameliorating climate change and that it would be deployed to that end by a benign global planner. As Bill Clinton might have put it when he was a presidential candidate, "It's the climate, stupid."[3] While it generates important knowledge about the interactions of different climatic factors, such modeling also creates deeply unrealistic and overly optimistic projections of the effects of geoengineering, which are of limited value for policymaking.[4] As a foundation for negotiating governance—

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whether to enable or constrain the development and deployment of such technologies—such projections are dangerously incomplete and potentially misleading. They tell us little about climatic responses to nonideal—self-interested, malicious, or competing—deployments, and even less about political or cultural responses outside of the climate system. Some game-theoretical and futures scenario-building exercises have been undertaken to begin exploring broader implications, but although these relax the assumption of a unitary actor, they still tend to presume that deployment would follow a "climate logic" rather than reflecting other possible motivations such as national security or commercial advantage.

This essay argues that policy for governing solar geoengineering, in a world of multiple states, uneven power relations, and pervasive disinformation, demands better understanding of nonideal scenarios—especially those motivated by factors other than climatic outcomes—and their political, social, and ethical, as well as climatic, implications. Additionally, exploring such scenarios also carries risks of the securitization[5] of geoengineering knowledge and development, empowering malicious actors, reducing public scrutiny and international cooperation, and stimulating the development of "countergeoengineering" capabilities (mechanisms that could physically halt geoengineering activities, or directly counter their effects). As a result, such research poses ethical dilemmas and itself merits careful governance. This essay first summarizes the limitations of existing modeling and other scenario work and elaborates on the knowledge demands arising in alternative logics for geoengineering and nonideal scenarios, before turning to the political and ethical issues raised in broader scenario research. It then highlights a dilemma arising with the risks of securitization in this space and asks whether further research can be ethically justified in such circumstances. It concludes that further research cannot be ruled out and calls for better governance of solar geoengineering research.

Scenarios and Their Shortcomings

Earth system modeling has largely deployed two sorts of scenarios: simplified caricatures intended merely to validate the models and designed configurations of deployment aimed at delivering specific desirable climatic outcomes.[6] All this work presumes that climate logics would drive deployment, with the actors engaged in rational goal-seeking behaviors shaped by actual or expected climate outcomes. It also implicitly anticipates both a series of advances in deployment, attribution, and control technologies that would enable the carefully modulated and targeted deployment of geoengineering, and (almost always) a benign global planner.[7] The nature of the latter is rarely if ever specified, but whether it is imagined as a technocratic agency serving a multilateral negotiated agreement, a *de facto* hegemonic geoengineering power, or a "geoengineering club" of powerful nations,[8] such idealized modeling necessarily presents an overly optimistic picture of the potential of solar geoengineering to counter the impacts of climate change.[9]

Global geopolitics—especially since Russia's invasion of Ukraine—and the decades-long convoluted and contested negotiations over climate change policies suggest that globally coordinated solar geoengineering designed to minimize climate impacts is unlikely. Other scenarios and logics should be considered, including "plausible scenarios for normal accidents and for malicious use."[10] Some scholars have begun to explore possible geopolitical dimensions. A handful of game theory studies suggest that the prospect of solar geoengineering might facilitate climate agreement or coordination, although possibly at the cost of less mitigation.[11] Others have suggested that the availability of countergeoengineering techniques would reduce the likelihood of unilateral deployment but at a risk of "dangerous brinkmanship."[12] While they have moved beyond the idea of a "global planner," game-theoretical models remain abstract and simplified, and tend to retain the central presumption of a climate logic.

Other social and political scientists have undertaken more speculative futuring exercises to explore geopolitical scenarios and illustrate how political and social systems might react to (or demand) geoengineering interventions.[13] Such methods could encompass a broader range of nonideal deployments and motivations, despite their so-far-limited participation (largely involving Global North academics and students). However, the futuring field as yet exhibits the same pervasiveness of climate logics (whether global or national) for the deployment of solar geoengineering as does modeling, often explicit in the very framing or construction of the process.[14] These exercises also tend toward idealism, in the sense that they are typically designed to identify governance mechanisms to address or avert undesirable outcomes, rather than exploring the full gamut of what could go wrong in a world where governance itself is contested. Nonetheless, even where solar geoengineering is presumed to be technically feasible and controllable, and climate logics are the key drivers of intervention, many scenarios foresee elevated international tension, disruptive disinformation, and the possibility of military conflict between different countries or geopolitical blocs, whether divided on familiar lines or in new configurations.[15] War-gaming exercises are typically conducted outside of the public eye, but some that feature geoengineering have been mentioned or reported, albeit under conditions of confidentiality.[16] These also raise concerns about the potential of solar geoengineering interventions—or even just threats or claims thereof—to destabilize international relations.

Conflict is not the only reason to worry about nonideal scenarios. Substitution of solar geoengineering for emissions cuts would be another undesirable outcome. Even though this is sometimes preemptively dismissed by modelers,[17] some actors might treat the availability (or even promise) of solar geoengineering as a reason to delay or resist the phaseout of fossil fuels. Countries or companies with rich fossil fuel reserves, whose positions in energy supply chains give them geopolitical power or whose national cultures are highly dependent on fossil energy, might all be vulnerable to such temptations.[18] In this context, modeling of idealized scenarios that overlooks the technical or political limitations of solar geoengineering may actually exacerbate the risk of such "mitigation deterrence."[19] Mitigation deterrence might also arise through emergent effects (as opposed to intentional choices); for example, where optimistic projections of solar geoengineering based on idealized earth system models are reflected in economic models, carbon prices, and investment forecasts.[20]

Idealized scenarios would deploy solar geoengineering *in addition to* accelerated mitigation so as to reduce peak temperature rises, or to slow the rates of climate change, rather than reaching the same global temperature outcomes with more solar geoengineering and less mitigation.[21] By contrast, nonideal pathways in which solar geoengineering substitutes for possible emissions reductions can involve elevated climate risk, because the climatic forcing effects of solar geoengineering and greenhouse gases are not physically or spatially directly equivalent. Moreover, climatic risks also grow the more temperature rise is masked by solar geoengineering, as any abrupt termination of geoengineering would then mean accelerated global warming. Substitutive pathways would also involve elevated levels of other harms arising from continued fossil fuel use, such as deaths and ill health from particulate pollution, or environmental damage from oil spills.

To summarize, current solar geoengineering knowledge largely emerges from a consideration of scenarios that are idealized in at least three dimensions: they assume an unproven technical practicability; they assume the active pursuit, through governance, of normatively optimized climate outcomes; and they disregard the possibility of deployments motivated in part or in whole for reasons other than managing climate change. The next section focuses on this last concern.

Beyond Climate Logics

In practice, states or other actors may seek to deploy solar geoengineering following logics not only beyond but also other than reducing the impacts of climate change. U.S. start-up Make Sunsets has already attempted deployment for purely economic ends, releasing sulfur dioxide into the stratosphere in its efforts to sell "cooling credits." By definition, such a business model enables and legitimates continued counterbalancing emissions.[22] At a larger scale, the adoption of solar geoengineering could be used by oil-exporting states to justify continued exploitation of fossil fuels: Saudi Arabia already publicly advocates the use of carbon dioxide removal not as a supplement to emissions cuts, but as a means to extend fossil fuel use.[23] Such substitutive scenarios prioritize economic over climate logics, but we must also consider security-oriented geopolitical logics.

Security analysts fear the deployment—or disruption—of solar geoengineering as a tool for geopolitical advantage, or even as a reason to dominate near-Earth orbital space for the military advantage it might provide.[24] Concerns about the dual-use potential of geoengineering platforms for surveillance have also been raised before,[25] but with the more serious consideration of space-based geoengineering, the prospects of weaponization—either for satellite killing or, worse, as a platform for directing kinetic weapons to the earth's surface—have to be taken seriously (as would be the case for any orbital activities that might involve the manipulation and processing of near-Earth asteroids). This example offers perhaps the clearest contrast between the climate logic and potential security logics. Modelers typically present space-based solar geoengineering as a more expensive and technically challenging, yet controllable, way to "turn down the sun," involving a relatively desirable global distribution of climatic effects and more limited side effects compared to other geoengineering approaches.[26] But to (at least some) security analysts, space-based solar geoengineering implies military dominance by a climate hegemon or climate leviathan.[27]

There are sound geopolitical and economic reasons to anticipate other logics and motives. Geoengineering might be pursued as a means to maintain the neoliberal economy; to defend culturally valued "ways of life" in a form of societal securitization; as a "silver bullet" climate response for authoritarian regimes; as a means to sustain the fossil fuel–embedded military-industrial hegemony of the United States; or as a tool (intelligible in security logics) to seek relative advantage in climatic conditions.[28] Some of these motives involve risks not only of mitigation deterrence but also of conflict if geoengineering were deployed (or threatened) for geopolitical negotiating leverage, actively weaponized for military advantage,[29] or involved disinformation or misinterpretation of any deployment or extreme climatic events coinciding with deployment.

The word count constraints of this essay preclude discussing each of them in detail, but there are even more conceivable economic, cultural, and security motivations for developing or deploying solar geoengineering or countergeoengineering capabilities. These include bolstering national prestige and demonstrating technological prowess (as seen with outer space missions); obtaining the capacity to deter others from perceived undesirable deployment;[30] undermining an enemy's capabilities or strategic situation; improving one's own strategic capabilities (for instance, by freezing permafrost to enable military operations); aspiring to enhance agricultural productivity; or even deliberately counterbalancing the effects of enemy investments in mitigation.[31] Scenarios need to be developed that explore the implications of such deployments—not only in terms of climate outcomes[32] but also in terms of political, social, economic, and cultural outcomes. Considering logics beyond ameliorating climate impacts reinforces the need for knowledge that goes beyond the biophysical effects projected in climate models. As seen in debates at the UN Environment Assembly,[33] adequately assessing proposals for geoengineering requires a better understanding of the geopolitical, legal, ethical, cultural, and economic implications and risks.

Exploring Nonideal Scenarios

None of the foregoing is to suggest we should abandon scenarios or modeling. However, in this context, there is a strong case for not only widening the set of scenarios we consider, and thus speculating more broadly,[34] but also for developing more diverse methods for creating and assessing scenarios so as to generate more useful knowledge. Arguably, we need to speculate differently, and perhaps "calculate" less. Rather than trying to extend formal calculative methods into political and social responses, we might find more value in applying participative, deliberative, and interactive methods, including "serious games" (such as war games).[35]

Modeling efforts that explore nonideal scenarios are limited by the capabilities and parameters of Earth system models. Some modelers have sought to characterize nonideal scenarios by their effects on the physical characteristics of a deployment—for example, might the scenario lead to overcooling or unscheduled termination?[36] They have not considered unilateral, uncoordinated, or competing deployments, and evaluate their scenarios in purely biophysical terms.[37] While valuable, such an approach is not only incomplete but also risks adding to the false optimism of technocratic modeling, which has, in so many domains, increased humanity's vulnerability to emergent shocks in adaptive systems.[38] Put simply, the more we treat models as "truth machines" able to define and help us manage a predictable set of futures, the more likely we are to push those systems to their limits, or to ignore the prospects of previously unseen adaptive system behaviors.

This is not to suggest that Earth system modeling could or should be used to try to predict geopolitical implications but rather to note that such modeling must be better contextualized and embedded in an iterative analysis of broader systemic effects if it is to avoid overlooking risks that arise outside of the biophysical domain. For example, some scholars have attempted to develop political scenarios to explore the plausibility of solar geoengineering deployment by, and in the interests of, a single state. Florian Rabitz concludes that several major powers might have the capacities to initiate and sustain such unilateral deployment, based on the consideration of access to relevant technologies; geographical access for infrastructure; and the power to resist deterrence by diplomacy, sanctions, or military countermeasures.[39] David Victor also predicts that states or (deniable) agents thereof are likelier to unilaterally deploy these projects than is presumed in the modeling literature.[40] But such scholars still focus on *climatic outcomes*, which ignores the potential for unilateral deployment based on other logics. Even limited unilateral deployment for alternative ends might still lead to highly disruptive political outcomes. Generally, therefore, the literature has so far largely simplified unilateralism as a matter of whether or not solar geoengineering might be successfully deployed, rather than considering the geopolitical implications of the processes through which such a move might be enabled, blocked, or diverted. Clearly, unilateral deployments need to be part of our future set of scenarios regardless of whether earth system models can capture their effects.

So how should we supplement the modeling in developing and exploring scenarios? One possibility would be a community climate scenario process, involving stakeholders and citizens, to inform broader social and governance pathway choices involving geoengineering.[41] The resultant scenarios would enable a broader characterization of the uncertainties of, and policy choices for, solar geoengineering and could foster a critical appraisal of its risks and benefits. Nonetheless, such an exercise would need to explicitly consider alternative logics for geoengineering, beyond "delivering climate goals," to ensure attention to all potential risks.

Reconfigured futuring exercises with a broader range of participants could also help generate a wider set of scenarios, especially if deliberately framed to include alternative nonclimate logics, and to explore worst-case outcomes, risk cascades, and so on. A recent participatory evolution (ParEvo) exercise—in which participants collectively develop narrative scenarios over multiple episodes—generated a broad range of possibilities by encouraging participants to explore catastrophic outcomes, and did so despite the limited diversity of participants and their predominant application of climate logics.[42] It highlighted possibilities for interactions with other risk factors or for risk cascades (in which one risk in turn generates or exacerbates another), more familiar conflict triggers, and nonoptimal configurations of solar geoengineering with harmful side effects. The scenarios created in this exercise indicated multiple ways in which the pursuit of solar geoengineering might worsen climate outcomes or generate other serious harms. The narratives included the following: (1) a climate breakdown from "cocktail geoengineering," with multiple techniques being attempted by diverse actors with no coordination; (2) a loss of control over target climate outcomes under AI-controlled geoengineering; (3) global overcooling as a result of the unregulated sale of cooling credits in speculative bubbles—also generating a large suppressed termination shock risk; (4) poorly planned polar-focused stratospheric aerosol injection in response to a permafrost virus release pandemic, with a high risk of asymmetric cooling and harmful impacts on monsoon climates; (5) efforts at space-based solar radiation modification leading to an accidental satellite wipeout; and (6) prolonged disagreement on climate measures due to elevated contestation over loss and damage and adaptation funding, as a consequence of widespread weather disruption arising from politically unstable unilateral stratospheric aerosol injection.[43]

What sort of scenarios should be examined to help understand the governance challenge of steering or constraining solar geoengineering? The narratives described above would suggest a need to supplement initial modeling efforts[44] with modeling and broader analysis that examines the deliberate substitution of emissions cuts; randomly varying levels of stratospheric aerosol injection with diverse injection points; various levels of solar geoengineering deployment unbalanced between the Northern and Southern hemispheres; solar geoengineering deliberately intended to redistribute rainfall, cause drought, or disrupt monsoons; cocktail geoengineering of multiple forms simultaneously; and efforts at deliberate countergeoengineering through the use of warming agents.

Further (geo)political scenario building and speculation is needed, bringing together geopolitical insights with analysis of risk cascades and systemic risks in precarious systems.[45] We saw in recent years how the impacts of the COVID-19 pandemic generated harmful risk cascades by overloading healthcare systems; overstretching economies built around long-distance trade, just-in-time delivery, and precarious labor forces; and raising international (and internal) tensions and conflict through the cultural transmission of disinformation. It might prove illuminating to gather some dystopian security analysts to speculate on what "enemies" might try to do with geoengineering, including covert or deniable deployments.[46]

But here is the rub: security analysts are indeed interested in solar geoengineering and its disruptive effects,[47] and this means they also express a demand for exploration of nonideal scenarios. But they do not necessarily want such knowledge to be widely shared. Like cyber exploits and nuclear technologies, solar geoengineering is seen as potentially of national security interest—a capability to be hoarded and protected, not transparently shared and debated.[48] And as Danielle Young shows in her contribution to this roundtable, scientists and researchers soon lose control of such technologies when governance and deployment decisions are driven by national security concerns and actors.

This suggests an ethical dilemma: in seeking to improve our knowledge of the risks associated with nonideal deployment of solar geoengineering, we would seem to both increase the possibility of nonideal deployment and reduce the prospect of a globally governed closer-to-ideal deployment (if such a prospect were to become desirable). The next section discusses some of the risks of exploring nonideal scenarios, focusing in particular on routes by which solar geoengineering knowledge might be securitized.

Risks Associated with the Securitization of Geoengineering Knowledge

Policymakers need to understand the implications of nonideal scenarios to help them judge what, if any, role solar geoengineering might play in future climate policy. Improved knowledge regarding the risks involved in nonideal deployments is essential for any process of risk assessment for solar geoengineering. Such assessments would rely on transparency and cooperation in knowledge generation, especially for stakeholders in the Global South, many of whom still lack the capacities to sufficiently evaluate the risks and benefits of solar geoengineering for their regions. Yet solar geoengineering is already often framed as a securitized exceptional measure, something beyond the purview of politics as usual that only comes into consideration because of the potentially catastrophic impacts of climate change.[49] The risks and possibilities associated with nonideal deployment scenarios make the securitization of solar geoengineering, and the knowledge about it, even more likely. Securitization typically is understood to transfer the issue into the domain of executive or military authority.

For military- and state-security stakeholders, knowledge about the risks involved in nonideal scenarios is essential for understanding what threat solar geoengineering might pose in the hands of an opponent or enemy power, and the extent of vulnerability and exposure to negative impacts that any given actor might face. Each state would wish to understand both its own and its enemies' (relative) vulnerability to such interventions, regardless of the ends to which they might be instigated. But each state would also wish to withhold such information from potential enemies. Geoengineering knowledge, therefore, risks becoming securitized and militarized (even though there seems little potential for the technologies to be used directly as weapons).

States will also be keen to understand how to defend themselves against the risks involved. Thus research into how to detect geoengineering interventions, and how to counter them, is emerging as a key part of the package promoted in military and security settings, alongside calls for governance measures including a research code of conduct.[50] Countergeoengineering might theoretically involve efforts to redistribute impacts or rebalance climate forcings[51] by further atmospheric interventions, or more conventional measures—from trade sanctions to cyber actions, or even military strikes to neutralize geoengineering facilities. Unilateral geoengineering might be deterred by such measures, but the development or use of such capabilities—perhaps even more than for solar geoengineering itself—could easily be viewed as a hostile act. Geoengineering research and development in a securitized context might thus engender an elevated risk of conflict.

Moreover, conducting research into such risks and vulnerabilities creates potentially dangerous knowledge. In "gain of function" research in virology, knowledge that could help combat a pandemic could—in the wrong hands—also be used to create one.[52] For potential bad-faith actors, knowledge of how geoengineering in particular configurations could disrupt weather patterns might create new opportunities to harm or threaten civilian populations. Security agencies might wish to know more about such prospects but may not be able to conceal such knowledge.

A similar parallel can be seen in cybersecurity. Security agencies seek to maintain exclusive knowledge of "exploits" that can give them access to systems for espionage, but should these exploits be known or discovered by their opponents, this knowledge would simultaneously increase the vulnerability of their own domestic entities.[53] In the case of solar geoengineering, even if the relevant knowledge were available, the capacity to undertake long-term interventions with sustained global impact may not be available to terrorist or insurgent groups, or even many states.[54] But small-scale interventions designed merely to demonstrate the potential to intervene or simply to disrupt regional or global climates might prove much easier.

Solar geoengineering is already entangled in disinformation and conspiracies, and securitized knowledge generation would likely exacerbate these reactions.[55] If militaries seek to obtain but limit the spread of knowledge about solar geoengineering and its deployment, then "chemtrail"-style geoengineering conspiracies[56] would become harder to extinguish, as we have seen with the persistence of the lab-leak theory about the origin of COVID-19, which seems in part to have been fueled by the suspicion that military interests were being served in gain of function research. Moreover, disinformation about geoengineering might also be deployed by state actors or extremist groups to inflame political or international tensions.[57] Once again we see that the securitization of geoengineering knowledge might paradoxically increase its risk. Even in the most idealized scenarios, extreme weather events will continue to occur, and disinformation that blames such events on geoengineering could be used to stir up opposition to governments and regimes deploying (or claimed to be deploying) the techniques. For instance, it is easy to imagine jihadist groups in West and Central Africa blaming droughts on U.S.-led geoengineering to rally support for insurgency against governments seen as Western sympathizers.[58] Reduced transparency around militarized or securitized geoengineering research and development would make such efforts harder to counter.

More generally, securitization raises concerns regarding reduced democratic participation, transparency, and accountability. This could exacerbate public distrust in official statements about geoengineering, as well as cultivate conditions in which human rights, civil liberties, and the rights of indigenous peoples might be disregarded in experimentation or deployment activities. Moreover, securitization could limit international cooperation and undermine the prospects for a collaborative international governance of geoengineering. Mutual deterrence might establish a *de facto* ban on geoengineering deployment but fuel a proliferation of geoengineering and countergeoengineering capabilities.[59] The more solar geoengineering knowledge is securitized, the more subsequent deployment might be securitized.

Furthermore, repertoires of risk management under securitization are often those of emergency response, where the urgency of the situation militates against democratic deliberation.[60] It is important therefore to consider how the securitization of geoengineering might affect how it is understood in temporal terms. Geoengineering scholars have tended to reject the idea that the techniques offer a suitable emergency response to escalating climate impacts.[61] However, although there is little evidence on how military or security authorities might respond, in war-gaming exercises, military experts reportedly turn to geoengineering later than scientists, and only when climate impacts translate into serious security threats.[62] The potential preemptive deployment envisioned by some geoengineering researchers may be discouraged by military experts' understanding of the ethical obstacles to preemptive military action. Although some nations have developed doctrines of preemptive self-defense, the conditions under which preemptive military action is considered justifiable are generally tightly constrained.[63]

Given the diverse and serious risks of securitization that may be realized once nonideal scenarios of solar geoengineering have been considered, we should ask whether further research into solar geoengineering can be ethically justified.

Ethical Considerations regarding Further Research

The previous section sketched the ethical dilemmas raised by the potential securitization of geoengineering knowledge relating to nonideal deployments. In this light, how might decisions to research solar geoengineering be justified?

Even for idealized scenarios of solar geoengineering, ethical justifications for research typically take the form of a "lesser evil" claim: that the harms involved in deployment might be less severe than those of what is described as "unavoidable" climate change. Yet the ethics of such a calculus are not as clear-cut as they might appear. Including nonideal scenarios highlights that the risks involved in geoengineering options may be greater than implied by idealized modeling. However, they may still be less than those of otherwise unabated climate change.

Moreover, as Jonathan Symons notes, such a consequentialist search for the lesser evil is a standard element of classical realist ethics.[64] Such an analysis "assumes highly imperfect compliance with the demands of justice, and is concerned with feasibility and transition rather than end-states. Classical realists urge leaders to prioritize state security over private moral concerns, to assess rival policies against their likely consequences and to seek the 'lesser evil' among feasible choices."[65] Lesser-evil choices are particularly appealing if the alternative is catastrophic or existential risk.

However, there are also reasons to believe that such a comparison of harms is not itself the most appropriate approach. Stephen Gardiner fears that the "lesser evil" justification would be susceptible to "moral corruption,"[66] a phenomenon in which choices made are not in line with justice but in line with the convenience and interest of those with the power to decide. In this case, if the only responses perceived as feasible are those compatible with the interests of the powerful countries and wealthy elites shaping the policy decisions, then the "choice between evils" may be false. If geoengineering is seen as the lesser evil, because the alternative is unavoidable climate change, then it matters how what is considered unavoidable is determined. What level of climate change can be considered unavoidable depends on which responses are seen as practical and legitimate. If "exceptional measures" are legitimately acceptable, then radical measures to phase out fossil fuels, overturn consumerist values and behaviors, or even to embrace "degrowth" should be considered alongside the dominant model of technological innovation and market-based policies. In other words, the lesser evil argument rests not only on a false binary but also on a moral failing, in that the "greater evil" of unavoidable climate change is a product of the self-interested decisions of those currently in power. This need not imply with certainty that the geoengineering option should be abandoned; it could rather require that additional compensatory or reparational obligations would accompany any choice to pursue geoengineering.

Nonetheless, even if a wider range of alternatives should be considered, or if the choice of a geoengineering pathway might be considered to create additional ethical obligations for its instigators, knowledge about the possibilities of nonideal geoengineering deployments will still be needed.

Scholars in both moral philosophy and security studies have proposed various criteria and conditions that might help us judge the ethical acceptability of solar geoengineering (and thus of the continued research into it) in the light of plausible deployment scenarios. All of these begin from a presumption that geoengineering is risky and would not be ethically justified in an ideal world. Drawing on just war theory, Rita Floyd suggests that securitizing an issue, and mobilizing an "exceptional response" such as solar geoengineering, is ethically justifiable when the following conditions are met: the threat is genuinely "existential"; the threatened object (such as national security or the social order) is itself morally just and therefore merits protection; the actor concerned has a genuine intent to protect that referent object (that is, that there is no moral corruption); and the intervention is both proportionate and more feasible than alternative responses.[67] Elizabeth Chalecki and Lisa Ferrari defend conditions that "just geoengineering" should meet, consistent with just war theory: the proposed geoengineering project should be ordered by a "competent authority" (for instance, requiring UN approval); be proportional; be discriminate (avoiding collateral damage to other nations or populations); be the only option with no reasonable alternatives; have a reasonable chance of success; and have a time-limited deployment.[68]

Moral philosophers David Morrow and Toby Svoboda argue that solar geoengineering may be ethically justified even in the absence of an existential threat.[69] They argue that solar geoengineering could be legitimate in less-than-dire circumstances if it worked to lessen climate injustice. This outcome would seem much less likely in most nonideal deployment scenarios, but to evaluate it would require further research. Morrow and Svoboda also advocate additional criteria: like other nonideal interventions—such as punishment and protection—geoengineering must be both morally proportionate and comparatively better than other politically feasible alternatives. These scholars think it unlikely that any specific deployment of solar geoengineering will prove *simultaneously* politically feasible *and* morally justifiable (even assuming a choice between "evils"). We might note that deployment scenarios following nonclimate logics would seem even less likely to meet the conditions of both political feasibility and moral justifiability.

It should be clear that many forms of nonideal deployment—such as those intended to maintain fossil fuel profits, or unilaterally undertaken to sustain geopolitical power advantages—fail immediately against any such set of ethical criteria. Yet, as we have seen, there are good reasons to explore such scenarios, and the risks associated with such research. And even if—on balance—it would seem ethically irresponsible to pursue further research, such reservations carry little weight in practical political and commercial decisions. In conclusion, then, it is worth considering ways in which these risks might be mitigated.

Ways Forward

The risks associated with the securitization of knowledge about nonideal scenarios of geoengineering are both significant and imminent. As a result, more research into solar geoengineering cannot be expected to reduce uncertainty but rather to establish new domains of uncertainty. Worse, more research might even increase the risks involved rather than reduce them. However, in the absence of nonideal scenario research, there are still serious risks due to overoptimism about solar geoengineering potential, whether because models inappropriately substitute geoengineering for mitigation or downplay the possibilities that deployments would exacerbate international tensions or lead to conflict. We should therefore not seek to prevent research but rather must govern it with care.

Solar geoengineering research should be governed with tools for responsible research and innovation to ensure that, for example, potential dual-use applications are identified early and their risks assessed.[70] All research should be subject to early and appropriate ethical review and advance approval, including assessments of how risks associated with nonideal scenarios are being mitigated. Standards for transparency and openness regarding research should be imposed, and funding should be regulated to minimize the risks of securitization. In practice, scenario research should involve more iteration or collaboration between Earth system modeling and narrative futuring work. This would both expand the family of Earth system scenarios by including a third generation focused on political realism (in the international relations disciplinary sense) to explore the climatic effects of self-interested, malicious, and competing deployments and also extend the toolset for projecting possible futures with geoengineering. Research should also include symmetric risk-risk analysis of nonideal scenarios.[71]

The prospect of nonideal deployments not only demands more comprehensive governance of research but also confirms that solar geoengineering should be understood as an exceptional response to climate change. This has two important implications. First, we should take care to avoid normalizing geoengineering (and the misplaced fungibility and substitution that doing so would engender), and eschew technocratic risk trade-off approaches that rely on such misplaced fungibility.[72] Integration into politics as usual is not an ethical way to treat an exceptional response—it instead needs to be assessed alongside other exceptional responses, such as securitized "war footing" emissions reduction, coordinated degrowth, and the opening of borders to facilitate climate migration. However, and second, we should aim to avoid state securitization of the issue, which would further undermine the trust and cooperation necessary for effective climate action. We should question the assumption that "emergency" means decision-making by executive fiat in the interests of nation-states (which are, in a global climate emergency, somewhat contradictory goals) and instead examine prospects for securitization from below, and the development of tools for "emergency democracy."[73] In such a setting, research into the nonideal scenarios of solar geoengineering might generate really useful knowledge.

Notes

1 National Academy of Sciences, Engineering, Medicine, *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance* (Washington, D.C.: National Academies Press, 2021).

2 Aslak-Antti Oksanen, "Dimming the Midnight Sun? Implications of the Sámi Council's Intervention against the SCoPEx Project," *Frontiers in Climate* 5 (2023), pp. 1–12; Katharine Ricke, "Solar Geoengineering Is Scary—That's Why We Should Research It," *Nature* 614 (February 2023); and Frank Biermann, Jeroen Oomen, Aarti Gupta, Saleem H. Ali, Ken Conca, Maarten A. Hajer, Prakash Kashwan, et al., "Solar Geoengineering: The Case for an International Non-Use Agreement," *WIRES Climate Change* 13, no. 3 (2022).

3 The phrase "it's the economy stupid" coined by Clinton's chief political adviser James Carville in 1992 has become a template model for political slogans (see politicaldictionary.com/words/its-the-economy-stupid/).

4 Duncan McLaren, "Whose Climate and Whose Ethics? Conceptions of Justice in Solar Geoengineering Modelling," *Energy Research & Social Science* 44 (October 2018), pp. 209–21; and Ben Kravitz, Douglas G. MacMartin, Hailong Wang, and Philip J. Rasch, "Geoengineering as a Design Problem," *Earth System Dynamics* 7, no. 2 (May 2016), pp. 469–97.

5 "Securitization" refers to the process whereby an issue is declared to be a matter of security, justifying exceptional responses, under the authority of political executive and/or military leaders. See Barry Buzan, Ole Wæver, and Jaap de Wilde, *Security: A New Framework for Analysis* (Boulder, Colo.: Lynne Rienner, 1998).

6 Ben Kravitz, Alan Robock, Olivier Boucher, Hauke Schmidt, Karl E. Taylor, Georgiy Stenchikov, and Michael Schulz, "The Geoengineering Model Intercomparison Project (GeoMIP)," *Atmospheric Science Letters* 12, no. 2 (2011), pp. 163–67; Simone Tilmes, Jadwiga H. Richter, Ben Kravitz, Douglas G. MacMartin, Michael J. Mills, Isla R. Simpson, Anne S. Glanville, et al., "CESM1 (WACCM) Stratospheric Aerosol Geoengineering Large Ensemble Project," *Bulletin of the American Meteorological Society* 99, no. 11 (November 2018), pp. 2361–71; and Peter Irvine, Kerry Emanuel, Jie He, Larry W. Horowitz, Gabriel Vecchi, and David Keith, "Halving Warming with Idealized Solar Geoengineering Moderates Key Climate Hazards," *Nature Climate Change* 9, no. 4 (April 2019), pp. 295–99.

7 McLaren, "Whose Climate and Whose Ethics?"; Duncan McLaren and Olaf Corry, "Clash of Geofutures and the Remaking of Planetary Order: Faultlines Underlying Conflicts over Geoengineering Governance," *Global Policy* 12, no. S1 (January 2021), pp. 20–33.

8 Joel Wainwright and Geoff Mann, *Climate Leviathan: A Political Theory of Our Planetary Future* (London: Verso, 2018); and David G. Victor, "Toward Effective International Cooperation on Climate Change: Numbers, Interests and Institutions," *Global Environmental Politics* 6, no. 3 (August 2006), pp. 90–103.

9 The Degrees Initiative, previously the Decimals project of the Solar Radiation Management Governance Initiative, has funded modeling work in institutions in the Global South to address Southern-inspired climate questions. Such modeling undoubtedly provides valuable regional detail and policy-relevant information to Global South governments. However, it is still susceptible to the presumption of a climate logic and a (now better-informed) benign global planner.

10 David W. Keith, "Toward a Responsible Solar Geoengineering Research Program," *Issues in Science and Technology* 33, no. 3 (Spring 2017).

[11] Adrien Fabre and Gernot Wagner, "Availability of Risky Geoengineering Can Make an Ambitious Climate Mitigation Agreement More Likely," *Humanities and Social Sciences Communications* 7, no. 1 (June 2020); and Piergiuseppe Pezzoli, Johannes Emmerling, and Massimo Tavoni, "SRM on the Table: the Role of Geoengineering for the Stability and Effectiveness of Climate Coalitions," *Climatic Change* 176, no. 10 (October 2023).

[12] Daniel Heyen, Joshua Horton, and Juan Moreno-Cruz, "Strategic Implications of Counter-geoengineering: Clash or Cooperation?," *Journal of Environmental Economics and Management* 95 (May 2019), pp. 153–77; and Andy Parker, Joshua Horton, and David Keith, "Stopping Solar Geoengineering through Technical Means: A Preliminary Assessment of Counter-Geoengineering," *Earth's Future* 6, no. 8 (2018), pp. 1058–65.

[13] See, for instance, Miranda Böttcher, Johannes Gabriel, and Sebastian Harnisch, "Scenarios on Stratospheric Albedo Modification in 2030" (workshop report of the German Research Foundation's Priority Program (SPP 1689) Scenario Workshop, Hamburg, March 22–24, 2015), www.researchgate.net/publication/282861086_Scenarios_on_Stratospheric_Albedo_Modification_in_2030; Jason J. Blackstock, Bidisha Banerjee, and Sean Low, "Scenario Planning for Solar Radiation Management" (workshop report and scenarios, Yale Climate and Energy Institute, August 2013), www.cigionline.org/static/documents/gswg1_scenario_planning_for_srm_august_2013.pdf; and Edward A. Parson and Jesse L. Reynolds, "Solar Geoengineering: Scenarios of Future Governance Challenges," *Futures* 133, 102806 (October 2021).

[14] The exercises described in Parson and Reynolds, "Solar Geoengineering," even mandated that solar geoengineering would face no technical obstacles (which removes one of the major real-world reasons that modeling work is idealized).

[15] See Blackstock, Banerjee, and Low, "Scenario Planning for Solar Radiation Management"; and Böttcher, Gabriel, and Harnisch, "Scenarios on Stratospheric Albedo Modification." These studies reveal deep uncertainties about how solar geoengineering might be politicized in different settings and the extent to which climate interests cut across existing geopolitical configurations.

[16] The information here was either disclosed under the Chatham House Rule or in nonattributable research interviews (undertaken with the ethical approval of the University of Copenhagen).

[17] This appears to be not a willful disregard but merely an inappropriate transposition of findings to the international scale from individual-scale studies suggesting that *individuals* do not appear to reduce commitment to emissions reduction when exposed to ideas of solar geoengineering (see, for example, Christine Merk, Gert Pönitzsch, and Katrin Rehdanz, "Knowledge about Aerosol Injection Does Not Reduce Individual Mitigation Efforts," *Environmental Research Letters* 11, no. 5 [2016]).

[18] Duncan McLaren and Olaf Corry, "'Our Way of Life Is Not Up for Negotiation!': Climate Interventions in the Shadow of 'Societal Security,'" *Global Security Quarterly* 3, no. 3 (July 2023), pp. 1–14; and Kevin Surprise, "Geopolitical Ecology of Solar Geoengineering: from a 'Logic of Multilateralism' to Logics of Militarization," *Journal of Political Ecology* 27, no. 1 (2020), pp. 213–35.

[19] Duncan McLaren, "Mitigation Deterrence and the 'Moral Hazard' in Solar Radiation Management," *Earth's Future* 4, no. 12 (2016), pp. 596–602.

[20] This problem is exacerbated by research introducing solar geoengineering into integrated assessment models (IAMs). See, for instance, Mariia Belaia, Juan B. Moreno-Cruz, and David W. Keith, "Optimal climate Policy in 3D: Mitigation, Carbon Removal, and Solar Geoengineering," *Climate Change Economics* 12, no. 3 (August 2021). Because these models cannot easily incorporate the risks of nonideal solar geoengineering, and presume a false fungibility between solar geoengineering and emissions reduction, they recommend least-cost "optimal" pathways with reduced mitigation as solar geoengineering is introduced. This reflects the basically utilitarian ethics of such modeling, which in IAMs underpins the misplaced presumptions of fungibility between interventions (see McLaren, "Mitigation Deterrence and the 'Moral Hazard'").

[21] See, for example, Irvine et al, "Halving Warming with Idealized Solar Geoengineering Moderates Key Climate Hazards."

[22] Michael S. Diamond, Kelly Wanser, and Olivier Boucher, "'Cooling Credits' Are Not a Viable Climate Solution," *Climatic Change* 176, art. 96 (July 2023).

[23] United Nations Environment Assembly national delegate statements, cited in McLaren and Corry, "Clash of Geofutures and the Remaking of Planetary Order."

[24] Steve Brock, Oliver-Leighton Barrett, Laura Birkman, Elisabeth Dick, Leah Emanual, Sherri Goodman, Kate Guy, et al., *The World Climate and Security Report 2021: A Product of the Expert Group of the International Military Council on Climate and Security* (Munich: Center for Climate and Security, Council on Strategic Risks, June 2021); Stewart M. Patrick, *Reflecting Sunlight to Reduce Climate Risk: Priorities for Research and International Cooperation*, Council Special Report No. 93 (Washington, D.C.: Council on Foreign Relations, April 2022); and Olaf Corry, Duncan McLaren,

and Nikolaj Kornbech, "Scientific Models vs. Power Politics: How Security Experts Understand Solar Geoengineering," *Review of International Studies* (October 2024).

[25] This was one of the risks reviewed by the SPICE (Stratospheric Particle Injection for Climate Engineering) project team as part of the stage-gate exercise. See Phil MacNaghten and Richard Owen, "Environmental Science: Good Governance for Geoengineering," *Nature* 479, no. 293 (November 2011).

[26] Chad M. Baum, Sean Low, and Benjamin K. Sovacool, "Between the Sun and Us: Expert Perceptions on the Innovation, Policy, and Deep Uncertainties of Space-Based Solar Geoengineering," *Renewable and Sustainable Energy Reviews* 158, 112179 (April 2022).

[27] Wainwright and Mann, *Climate Leviathan*.

[28] Konrad K. Ott, "On the Political Economy of Solar Radiation Management," *Frontiers in Environmental Science* 6, no. 43 (May 2018); McLaren and Corry, "'Our Way of Life Is Not Up for Negotiation!'"; Axel Michaelowa, "Solar Radiation Modification—A 'Silver Bullet' Climate Policy for Populist and Authoritarian Regimes?," in "Governing Climate-Altering Approaches," special issue, *Global Policy* 12, no. S1 (April 2021), pp. 119–28; Surprise, "Geopolitical Ecology of Solar Geoengineering"; and Danielle N. Young, "Considering Stratospheric Aerosol Injections beyond an Environmental Frame: The Intelligible 'Emergency' Techno-Fix and Preemptive Security," *European Journal of International Security* 8, no. 2 (May 2023), pp. 262–80.

[29] See Benjamin K. Sovacool, Chad Baum, and Sean Low, "The Next Climate War? Statecraft, Security, and Weaponization in the Geopolitics of a Low-Carbon Future," *Energy Strategy Reviews* 45, 101031 (January 2023). While it is generally agreed that solar geoengineering cannot technically be deployed as a targeted weapon, it could still be weaponized in the sense of delivering relative advantages; for example, by changing or destabilizing climatic conditions that currently favor a perceived opponent.

[30] Security analysts tend to predict a state of "mutually assured deterrence," in which the great powers all obtain solar geoengineering and countergeoengineering capabilities so as to prevent any deployment that would be to their disadvantage (see Corry, McLaren, and Kornbech, "Scientific Models vs. Power Politics"). Such an outcome would suggest little prospect for globally coordinated, idealized solar geoengineering.

[31] Such an effort would more likely be intended to fuel domestic political disruption than to produce specific climate impacts.

[32] Douglas G. MacMartin, Daniele Visioni, Ben Kravitz, Jadwiga H. Richter, Tyler Felgenhauer, Walker R. Lee, David R. Morrow, Edward A. Parson, and Masahiro Sugiyama, "Scenarios for Modeling Solar Radiation Modification," *Proceedings of the National Academy of Sciences* 119, no. 33, art. e2202230119 (August 2022).

[33] The most recent of these debates, in March 2024, is reported in the following: Duncan McLaren and Olaf Corry, "The Global Conversation about Solar Geoengineering Just Changed at the UN Environment Assembly. Here's How," LegalPlanet, March 8, 2024, legal-planet.org/2024/03/08/the-global-conversation-about-solar-geoengineering-just-changed/.

[34] Edward A. Parson, "Useful Global-Change Scenarios: Current Issues and Challenges," *Environmental Research Letters* 3, no. 4, 045016 (2008).

[35] Carina Bachofen, Nick Fortugno, Jarrod Goentzel, Paulo Gonçalves, Natasha Grist, Colleen Macklin, Janot Mendler de Suarez, et al., *Games for a New Climate: Experiencing the Complexity of Future Risks* (Frederick S. Pardee Center, Boston University, November 2012).

[36] MacMartin et al., "Scenarios for Modeling Solar Radiation Modification."

[37] This excludes unilateral deployment—with all its potential to trigger political contestation and even conflict—on the tendentious grounds that such "crises would play out … over such a short period [months or a year or so, that], the deployment would not have scaled up to detectable cooling" making it geophysically insignificant. See ibid., p. 2.

[38] Adam Toon, *Models as Make-Believe: Imagination, Fiction and Scientific Representation* (New York: Palgrave Macmillan, 2012).

[39] Florian Rabitz, "Going Rogue? Scenarios for Unilateral Geoengineering," *Futures* 84, pt. A (November 2016), pp. 98–107.

[40] David G. Victor, "Governing the Deployment of Geoengineering: Institutions, Preparedness, and the Problem of Rogue Actors," in Robert N. Stavins and Robert C. Stowe, eds., *Governance of the Deployment of Solar Geoengineering* (Cambridge, Mass.: Harvard Project on Climate Agreements, February 2019), pp. 41–44.

[41] Masahiro Sugiyama, Yosuke Arino, Takanobu Kosugi, Atsushi Kurosawa, and Shingo Watanabe, "Next Steps in Geoengineering Scenario Research: Limited Deployment Scenarios and Beyond," *Climate Policy* 18, no. 6 (2018), pp. 681–89.

[42] Gideon Futerman and S.J. Beard, *Report of a workshop on Managing the contribution of Solar Radiation Modification and Climate Change to Global Catastrophic Risk*, Centre for the Study of Existential Risk, www.cser.ac.uk/media/uploads/files/SRM_workshop_report_003.pdf.

[43] Ibid. Also draws on the scenarios of the ParEvo exercise reported here and available from the authors.

[44] MacMartin, et al., "Scenarios for Modeling Solar Radiation Modification."

[45] The case for considering extreme plausible risks, not just the more probable ones, is made by several authors. See Luke Kemp, Chi Xu, Joanna Depledge, Kristie L. Ebi, Goodwin Gibbins, Timothy A. Kohler, Johan Rockström, et al., "Climate Endgame: Exploring Catastrophic Climate Change Scenarios," *PNAS*, 119 no. 34 (August 1, 2022); Aaron Tang and Luke Kemp, "A Fate Worse than Warming? Stratospheric Aerosol Injection and Global Catastrophic Risk," *Frontiers in Climate* 3 (November 18, 2021); and Seth D. Baum and Anthony M. Barrett, "Global Catastrophes: The Most Extreme Risks," in Vicki M. Bier, ed., *Risk in Extreme Environments: Preparing, Avoiding, Mitigating, and Managing* (New York: Routledge, 2017), pp. 174–84.

[46] Entirely covert geoengineering is difficult to envisage: Atmospheric changes would be detectable through existing satellite surveillance, as would the construction of facilities for large-scale deployment. However, cyberwarfare activities have indicated there is a broad space between secret and deniable in which bad-faith actors can operate.

[47] Brock et al., *World Climate and Security Report 2021*; and Patrick, *Reflecting Sunlight to Reduce Climate Risk*.

[48] Corry, McLaren, and Kornbech, "Scientific Models vs. Power Politics."

[49] Duncan McLaren, "Governing Emerging Solar Geoengineering: A Role for Risk-Risk Evaluation?," *Georgetown Journal of International Affairs* 24, no. 2 (Fall 2023), pp. 234–43.

[50] See, for example, Joseph Versen, Zaruhi Mnatsakanyan, and Johannes Urpelainen, "Preparing the United States for Security and Governance in a Geoengineering Future," Brookings, December 14, 2021, www.brookings.edu/articles/preparing-the-united-states-for-security-and-governance-in-a-geoengineering-future/. The EU has called for exploration of geoengineering governance in its latest climate security statement. See European Commission, *Joint Communication to the European Parliament and the Council: A New Outlook on the Climate and Security Nexus; Addressing the Impact of Climate Change and Environmental Degradation on Peace, Security and Defence* (Brussels: High Representative of the Union for Foreign Affairs and Security Policy, 2023), www.eeas.europa.eu/sites/default/files/documents/2023/JOIN_2023_19_1_EN_ACT_part1_v7.pdf. The U.S. National Oceanic and Atmospheric Administration has already initiated research on baseline stratospheric conditions, in part to facilitate detection. However, this program was misrepresented in the Russian and, subsequently, Indian media as evidence of the weaponization of geoengineering.

[51] In this context, "forcing" is the technical term referring to factors that influence temperatures through influencing the radiative balance of the system.

[52] The United States developed an ethical framework for gain of function research based on the understanding that a conventional risk-benefit analysis was inadequate. It is noteworthy that additional considerations introduced include justice (the distribution of risks and benefits), democracy (reflecting public values), and international engagement. See Michael J. Selgelid, "Gain-of-Function Research: Ethical Analysis," *Science and Engineering Ethics* 22, no. 4 (August 2016), pp. 923–64.

[53] Nicole Perlroth, *This Is How They Tell Me the World Ends: The Cyber Weapons Arms Race* (London: Bloomsbury, 2021).

[54] Rabitz, "Going Rogue?"

[55] Rose Cairns, "Climates of Suspicion: 'Chemtrail' Conspiracy Narratives and the International Politics of Geoengineering," *Geographical Journal* 182, no. 1 (March 2016), pp. 70–84.

[56] The chemtrail conspiracy claims geoengineering is already occurring through the addition of chemicals to commercial jet fuel. See ibid.

[57] Corry, McLaren, and Kornbech, "Scientific Models vs. Power Politics."

[58] Ibid.

[59] Ibid.

[60] Nils Markusson, Franklin Ginn, Navraj Singh Ghaleigh, and Vivian Scott, "'In Case of Emergency Press Here': Framing Geoengineering as a Response to Dangerous Climate Change," *WIREs Climate Change* 5, no. 2 (March/April 2014), pp. 281–90.

[61] Joshua B. Horton, "The Emergency Framing of Solar Geoengineering: Time for a Different Approach," *Anthropocene Review* 2, no. 2 (2015), pp. 147–51.

[62] Corry, McLaren, and Kornbech, "Scientific Models vs. Power Politics."

[63] Sean D. Murphy, "The Doctrine of Preemptive Self-Defense," *Villanova Law Review* 50, no. 3 (2005).

[64] Jonathan Symons, "Realist Climate Ethics: Promoting Climate Ambition within the Classical Realist Tradition," *Review of International Studies* 45, no. 1 (January 2019), pp. 141–60.

[65] Ibid., p. 141.

[66] Stephen M. Gardiner, "Is 'Arming the Future' with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System," in Stephen M. Gardiner, Simon Caney, Dale Jamieson, and Henry Shue, eds., *Climate Ethics: Essential Readings* (Oxford: Oxford University Press, 2010), pp. 284–312.

[67] Rita Floyd, "Solar Geoengineering: The View from Just War/Securitization Theories," *Journal of Global Security Studies* 8, no. 2 (June 2023), pp. 1–15. Some of these criteria would likely generate controversy. For instance, using solar geoengineering to defend the current global system and its grossly uneven distribution of power and wealth might be seen by many as abhorrent.

[68] Elizabeth L. Chalecki and Lisa L. Ferrari, "A New Security Framework for Geoengineering," *Strategic Studies Quarterly* 12, no. 2 (Summer 2018), pp. 82–106.

[69] David Morrow and Toby Svoboda, "Geoengineering and Non-Ideal Theory," *Public Affairs Quarterly* 30, no. 1 (January 2016), pp. 83–102.

[70] Richard Owen, John R. Bessant, and Maggy Heintz, *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (Chichester, U.K.: Wiley, 2013).

[71] Edward A. Parson, "Geoengineering: Symmetric Precaution," *Science* 374, no. 6569 (November 11, 2021).

[72] McLaren, "Governing Emerging Solar Geoengineering."

[73] For emerging efforts in this direction, see Michael Albert, "Climate Emergency and Securitization Politics: Towards a Climate Politics of the Extraordinary," *Globalizations* 20, no. 4 (2023), pp. 533–47; D. Hine and D. McLaren, Climate Emergency: The Democracy Fork, *Open Democracy 11th December 2019.* www.opendemocracy.net/en/climate-emergency-democracy-fork/; Chris Maisano, "Don't Blow Up a Pipeline," *Jacobin*, July 29, 2023, jacobin.com/2023/07/climate-change-mass-politics-democracy-organizing-andreas-malm-bpra; and Afsoun Afsahi, Emily Beausoleil, Rikki Dean, Selen A. Ercan, and Jean-Paul Gagnon, "Democracy in a Global Emergency: Five Lessons from the COVID-19 Pandemic," *Democratic Theory* 7, no. 2 (Winter 2020), pp. 5–19.

Abstract: As part of the "Solar Geoengineering: Ethics, Governance, and International Politics" roundtable, this essay examines dilemmas arising in exploring nonideal scenarios of solar geoengineering deployment. Model-based knowledge about solar geoengineering tells us little about possible climatic responses to malicious, self-interested, or competing deployments, and even less about political or cultural responses outside of the climate system. The essay argues that policy for governing solar geoengineering in a world of multiple states and uneven power relations requires a broader base for solar geoengineering knowledge, beyond that offered by modeling, and a better understanding of nonideal scenarios, especially those motivated by logics beyond reducing climate impacts. It highlights the interests of military and security actors in such knowledge, and the potential for it to facilitate securitization and further reduce the prospect of multilateral collaborative governance of geoengineering in the public interest. The essay concludes that further research can be ethically justified but must be comprehensively governed.

Keywords: solar geoengineering, geopolitics, countergeoengineering, governance, nonideal scenarios, securitization, dangerous knowledge