The sky over the South China Sea, as seen from above. NASA 2006

A few months ago, Congress earmarked $4 million for the National Oceanic and Atmospheric Administration (NOAA) to research:

stratospheric conditions and the Earth's radiation budget, including the impact of the introduction of material into the stratosphere from changes in natural systems, increased air and space traffic, proposals to inject material to affect climate, and the assessment of solar climate interventions. Within these funds, the agreement further directs [NOAA Research] to improve the understanding of the impact of atmospheric aerosols on radiative forcing, as well as on the formation of clouds, precipitation, and extreme weather.

The language above has been widely interpreted as the "first" federally funded initiative to investigate solar geoengineering technology. Here Congress instructs NOAA Research to study conditions in the upper atmosphere to better understand how its workings influence our planet's flows of incoming and outgoing energy. These instructions could be fulfilled—and likely will be —through passive observation of the stratosphere and its natural changes. But the investigation would directly connect to research needed to assess solar

geoengineering proposals. For example, NOAA Research's observations could tell us more about how aerosols behave in the stratosphere, as well as how stratospheric changes impact weather in the sky below.

This development requires some concrete, practical thinking about geoengineering governance. If this appropriation is a first step toward a federal research program into solar geoengineering, what risks are involved? How should they be managed? What tools do we have to meet those goals? This post examines the National Environmental Policy Act (NEPA)—a federal law requiring environmental review of federal actions—as a springboard for federal geoengineering governance. NEPA has serious limitations for technological assessments, especially concerning future, speculative impacts. But in the right hands, NEPA can be a serviceable tool to engage public opinion, seek expert advice, and consider the environmental risks of an early research program.

Specifically, I recommend that NOAA Research complete a Programmatic Environmental Assessment (PEA) before launching an expanded stratosphere research program. It should be broad enough in its discussion to cover (a) observation of natural phenomena and (b) field experiments without significant impacts (that is, no effect on radiative forcing). The PEA could then later be incorporated into agency NEPA analysis of individual experiments, all of which would almost certainly qualify for categorical exclusions. NOAA Research wouldn't have to *do* any field experiments. But field experiments by others are likely in the foreseeable future (at least one would likely need federal approval by the FAA) and sufficiently linked to NOAA's research objectives to warrant overarching programmatic review.

Early Field Research into Solar Geoengineering

Solar geoengineering describes a suite of speculative technologies to alter the planet's energy balance to compensate for global warming. Of these techniques, the best understood and most discussed is "stratospheric aerosol injection" (SAI). An SAI program would introduce a thin "veil" of aerosols into the stratosphere, which, while suspended there, would reflect away a very small portion of incoming sunlight (perhaps about 1%), thus cooling the planet. This idea appears to be technically feasible, but it's very far off from any kind of deployment due to open questions about stratospheric chemistry and physics, as well as uncertainty about the distribution of effects down below. In the words of leading researcher Prof. David Keith, the question before us is not whether to deploy solar geoengineering. It's whether we should *research* solar geoengineering—enabling more informed decisionmaking by the generations that come after us.

Accordingly, field research into solar geoengineering would seek to answer basic questions of how the stratosphere behaves, how materials become distributed through it, and how stratospheric changes influence the troposphere below—the turbulent layer of the atmosphere where weather happens and we live. The data gathered would be in the service of improving models for depicting future climate change and hypothetical climate interventions. At this stage, and for the foreseeable future, field research would, by design, have vanishingly small impacts on the environment and no impact on climate or weather. To give one example, SCoPEx, a field experiment in development by Harvard's Solar Geoengineering Research Program (led in part by Prof. Keith) would release a couple of pounds of material into the stratosphere, and then observe its behavior and that of the surrounding air once introduced. The material released would be less than what a commercial airplane emits during "one minute of flight."

Concerns about solar geoengineering field research thus have little to do with its immediate impacts on the physical environment. They're driven instead by worries about consequences further down the road. A *slippery slope*, in that early research would commit us to bigger experiments, development of the technology, and, ultimately, deployment. A *moral hazard*, in that research would signal to policymakers and business leaders to take emissions cuts even less seriously than they already do. That it would be *intrinsically wrong* to tamper with nature this way, or that its deployment would be *inevitably unjust*. These concerns would apply just as well to Congress's research earmark because it's intended in part for the "assessment of solar climate interventions," and thus heads down the same (purportedly) slippery, morally hazardous path.

NEPA: purpose, design, and limits

The point of NEPA is to integrate environmental considerations into federal agency decisionmaking, as well as to assure the public the agency has considered those impacts.[1] It does so by requiring an environmental review process describing and analyzing the environmental impacts of proposed actions (including funding decisions and permit approvals). The bulk of impact analysis occurs through devising reasonable alternatives to the proposed action, and then comparing the environmental impacts of the different pathways. The agency must then describe the final action and explain why it was chosen.

Courts and agencies have created an elaborate administrative scheme for NEPA's implementation.[2] A few concepts are needed to avoid losing one's way:

- *Environmental Assessment (EA)*: Environmental review document prepared if the agency is unsure whether the proposal has significant impacts on the environment, or

where a proposal without significant impacts is unusual or extraordinary in some way;
- *Environmental Impact Statement (EIS)*: In-depth environmental review document prepared if the agency determines there will be significant impacts for the proposed action;
- *Programmatic NEPA Review (PEA or PEIS)*: A broad, high-level EA or EIS that examines the big-picture environmental consequences of a policy, often covering many interrelated federal actions; and
- *Categorical Exclusion (CE)*: Frequent or routine agency actions determined in advance to have no significant environmental impacts, therefore presenting no need to prepare an EA or an EIS.

Agencies retain discretion in how to structure their NEPA analyses' scope, detail, and outcome, provided they take a "hard look" at the environmental consequences of their proposals.[3] On judicial review, a court will defer to those determinations so long as they are reasonable.[4] If the analysis is found insufficient, the agency will be ordered to revise it. The proposed action may be enjoined in the meantime, depending on the circumstances of the case.[5]

NEPA is said to be "procedural" rather than "substantive."[6] It requires rigorous contemplation of environmental impacts, but doesn't mandate an environmentally friendly final decision by the agency.[7] It doesn't require agencies to commit to mitigation plans,[8] and agencies must consider only the reasonably foreseeable effects of their actions, and not the actions of others outside their control.[9] Also excluded are psychological harms caused by a proposed action, absent a significant physical change in the environment; risk of danger alone need not be analyzed.[10]

Getting the Most out of NEPA for a Solar Geoengineering Research Program

Scientific research tends to be characterized under NEPA as lacking environmental impacts, given "the long term effect of the accumulation of human knowledge . . . [is] basically speculative and unknowable in advance."[11] Initial field research into solar geoengineering—be it passive observation of the stratosphere by NOAA Research, or minimally intrusive manipulation like in SCoPEx—wouldn't produce "significant" impacts under NEPA. Moral hazard or slippery slope risks lack a sufficiently strong connection to the physical impacts of the experiments themselves. NOAA has provided for categorical exclusions (CEs) that could readily be applied to a stratospheric research program carrying out the objectives of the FY2020 Congressional appropriation. Applying a CE would obviate the need to do further NEPA analysis, such as an EA or EIS.

But that same NOAA guidance states that more in-depth analysis may be warranted in "extraordinary circumstances," such as "highly controversial environmental effects." (pp. 4–5). Furthermore, current implementing regulations for NEPA advise that "[a]n agency may . . . prepare environmental assessments" even when a categorical exclusion is applied,[12] while current CEQ guidance instructs that programmatic review can take the form of either an EA or EIS.[13] Pulling these principles together marks a path for more expansive NEPA review.

The first federal research program into solar climate interventions is certainly "extraordinary" and "highly controversial." It would be well within NOAA Research's discretion to launch a Programmatic Environmental Assessment (PEA) to explore the attendant risks and impacts. The PEA could then be incorporated by reference if NOAA Research applies categorical exclusions to individual experiments.

NOAA seems a good fit to lead such a review, with participation of agencies like the FAA and EPA, given its duties to research earth systems, protect marine environments, and manage living resources. Others appear to agree: A bill introduced in the House would expand NOAA Research's authority to receive reports and give recommendations on solar geoengineering field research (though it would still lack permitting authority).

The process could begin by publishing a request for public comment for scoping the PEA. This would allow for the National Academies of Sciences, Engineering and Medicine time to complete its report on research priorities and governance recommendations for solar geoengineering, which could then be incorporated in the final document. The NEPA process could also allow for ample opportunity for public comment and public hearings, with remarks noted and responded to within the PEA. The PEA could give *some* consideration of the more abstract risks associated with an early research program. It could also contemplate the risks of not doing research: of a warmer world, facing mounting climate harms, but lacking SAI knowledge and governance experience. Finally, the agency could commit itself to ongoing commitments to monitor developments in the field and revamp the PEA as necessary. Those would be binding commitments: Courts hold agencies accountable for promises and measures announced in final NEPA decisions.

Conclusion

Solar geoengineering research is contentious. There's a good chance that the outcome of any accompanying NEPA process would be challenged in court. It's unclear, however, how program opponents could prevail under NEPA given how far-flung deployment impacts are from initial field research. Moral hazard is beyond NEPA because federal agencies lack

authority over other countries' emissions,[14] while feelings of fear or distress at the prospect of research are also out of bounds, absent a strong connection to physical environmental impacts.[15] Whatever the agency decides to do under NEPA will therefore be on strong legal footing. It has *discretion* to engage in expansive review, but wouldn't be *required* to do so. That's why it's so important the right agency lead development of NEPA analysis, and that experts and engaged communities step up to shape vigorous environmental review.

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Footnotes

[1] *Weinberger v. Catholic Action of Hawaii*, 454 U.S. 139, 143 (1981).

[2] CEQ recently proposed an overhaul of NEPA's implementing regulations. Among other changes, it would controversially narrow the federal actions NEPA applies to, limit the range of effects that must be considered, and expand the role that non-government project proponents can play in developing environmental analysis. The rule will likely be finalized later this year, at which point it will almost certainly be challenged in court. The analysis in this post accounts for this rulemaking.

[3] *Kleppe v. Sierra Club*, 427 U.S. 390, 410 n.21 (1976).

[4] *Id.* at 412.

[5] *Monsanto v. Geertson Seed Farms*, 561 U.S. 139, 156–7 (2010).

[6] *Vermont Yankee Nuclear Power Corp. v. Natural Res. Def. Council, Inc.* 435 U.S. 519, 558 (1978).

[7] *Strycker's Bay Neighborhood Council, Inc. v. Karlen*, 444 U.S. 223, 227–29 (1980).

[8] *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 353 (1989).

[9] *Department of Transportation v. Public Citizen*, 541 U.S. 752, 767 (2004).

[10] *Metropolitan Edison Co. v. People Against Nuclear Energy*, 460 U.S. 766, 776 (1983).

[11] 45 C.F.R. Part 640.3(b) (National Science Foundation's implementing regulations for NEPA).

[12] 40 C.F.R. Part 1508.4. CEQ's proposed revision of these regulations uses similar "extraordinary circumstances" language with regard to categorical exclusions. CEQ, *Update to the Regulations Implementing the Procedural Provisions of NEPA*, 85 Fed. Reg. 1684, 1715 (Jan. 10, 2020) (proposed 40 C.F.R. Part 1501.4).

[13] The guidance interprets current implementing regulations, but CEQ uses essentially the same language in the corresponding section of its proposed update to the rules. *Compare* 40 C.F.R. Part 1501.4 *with* 85 Fed. Reg. at 1718 (proposed 40 C.F.R. Part 1502.4). It's therefore reasonable to infer that agencies would retain discretion to conduct a PEA or PEIS, especially considering that CEQ has rescinded other Obama-era guidance on NEPA, but not the Obama-era guidance on programmatic reviews.

[14] *See Public Citizen*, 541 U.S. at 770.

[15] *See Metropolitan Edison*, 440 U.S. at 776–78.