Geoengineering and Climate Policy: Risk, Knowledge, and Inertia

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National Academy of Sciences
Government University Industry Research Roundtable (GUIRR)
October 13, 2010

Good morning, and thanks for giving me this chance to talk about geoengineering. This is a unique topic, and I hope I can give you some sense of both the complexity of the issues and at the same time, what I believe are some simple, bottom-line truths about it.

In thinking about the implications of geoengineering for climate policy, we might start by turning the question around: What are the implications of climate policy—and climate science—as we see them today for geoengineering? In other words, before we ask what geoengineering can do for us, we must first ask: What should *we* do for geoengineering?

Geoengineering, after all, is little more than a concept at this point—a radical concept supported by promising but limited analysis and evidence, a concept with profound implications, countless complexities, and enormous uncertainties. We cannot know what role these ideas *should* play in the overall mix of climate policies until we know much more about the capabilities of different climate engineering techniques.

The broad term "geoengineering" contains an enormous diversity of ideas about ways one might alter features of the environment to either curtail the harmful *effects* of global warming through, for instance solar radiation management, or to counteract the *causes* of warming by using biological or chemical processes to remove carbon dioxide and other greenhouse gases from the atmosphere. Many of these technologies or techniques appear to have widely differing characteristics in terms of effectiveness, affordability, reliability and risks.

Our knowledge of even the most-studied geoengineering techniques is very limited. Before we can understand what role geoengineering might play in the broader suite of climate policy options, we have to decide whether to invest in a research program that will produce reliable information about different technologies and techniques. Absent such a program, we can only speculate about possible policy implications.

So, the immediate policy question about geoengineering now is: *Should the federal government embark upon a systematic, strategic effort to research these ideas* and, if they seem sufficiently promising, develop the technologies themselves and, crucially, the unique scientific, social, legal and political institutions that would be needed to deploy them?

I believe the answer is yes; such a research program is urgently needed. Climate change is a profound threat to life on earth as we know it, and I will argue, any climate policy that fails to include a strategic program to research the full dimensions of geoengineering cannot reliably protect us from the worst effects of global warming.

Geoengineering, therefore, may be the most important, or most dangerous, component of climate policy; only research can reduce its risks and improve our understanding of its potential capabilities.

The true value of geoengineering will not be known for many years. But what we know so far does suggest that, should the effects of climate change prove severe or even catastrophic—scenarios which are far from certain, but which appear increasingly plausible—geoengineering could be the only way of cooling the planet quickly, substantially, and sustainably. Done badly, however, geoengineering could add significant new risks to an already disturbed global ecosystem.

These twin threats—the risks of runaway warming, and the hazards of hasty geoengineering—constitute a compelling case for research. Refusal to study these technologies today will not forestall their eventual use, it will only ensure that future decisions about geoengineering will be handicapped by haste, ignorance, and incompetence.

You will hear many objections to geoengineering. It's too dangerous, too difficult, too complex to ever be feasible. Let me be clear: We should not research geoengineering *despite* its difficulty; we should begin research immediately *because* of its difficulty.

Geoengineering the global climate, particularly through solar radiation management, would be the largest, longest, and most complex engineering effort in human history. Pick your point of comparison—the Manhattan project, the Apollo program, the pyramids—they were all a walk in the park compared to geoengineering the global climate for a century or more.

The Manhattan project built the first nuclear bomb in less than four years. Apollo put the first man on the moon in less than a decade. By my own admittedly crude calculation, it would take *at least* 50—and more likely 60 or 70—years to research, develop, test, and—perhaps hardest of all, agree to deploy—a well-designed solar radiation management system that could cool the planet and operate reliably for decades or even centuries.

The crucial phrase in that last sentence, however, was "well-designed." Because the time it would take to embark upon a *crude* geoengineering effort is probably quite short, and the technical and financial hurdles for such an effort are relatively low. So we are facing the likelihood that we will soon live in a world where a number of nations may be capable of incompetent geoengineering—but it may be quite some time before we would have much more than the dimmest idea what we're doing.

The question, therefore, is whether, in the time it takes for us to reach a level of competence in the field, will changes in the global climate force our hand? And by "our" hand, I mean humanity's, not America's, for in such a scenario, other nations—say, China, or India, or a group of African or Arctic nations—bearing the brunt of the damage, may well be the first to act.

How long before some nation decides to attempt geoengineering? I can't say, but I know at least one serious scientist who believes environmental conditions may prompt such an effort as early as the 2020s. I hope he's wrong.

If that risk seems real to you, then we cannot afford to delay research at all, and we should think carefully about crafting a program that is commensurate with the scale and scope of the challenge it aspires to meet. America is not likely to be the first nation to seriously contemplate geoengineering, but we should be at the forefront of the effort to learn all we can about it, and to develop the domestic and international scientific, social, political, and legal institutions that will be needed if the world is to have any hope of making wise choices when the moment is at hand.

I assume by now that at least a few of you are thinking "This is absolute madness—why in the world would anyone seriously contemplate such an absurd idea?" I've briefly sketched a defensive reason for geoengineering research; let me now try to lay out the more important proactive case for research by returning to my earlier question: What does the state of climate science and policy tell us today about the likelihood that we might find ourselves in a world where we might really want to use geoengineering?

These are very complex topics in their own right; in the interest of time, I'll make just a few simple points, starting with the state of climate policy today.

I believe the mitigation challenge is far greater than is widely appreciated, and we are much further from meeting it than most people understand.

There is no path forward toward any semblance of climate stability that does not require an extraordinary mobilization of low- and zero-emissions technologies over the next few decades. We are not even close to making this energy transition now; decades of hard work still lie ahead.

For instance, writing in *Science* last month, Marty Hoffert calculated that 30 terawatts of power from carbon-neutral sources will be needed by mid-century—yet we have not yet mobilized the resources to provide even one terawatt of carbon-neutral power. One can argue with those numbers, of course, but I suspect the broader picture they paint is not misleading.

And, while we work to change that picture, we should be clear about the likely pace of progress. Energy and transportation systems are highly capital-intensive and infrastructure-dependant; for a myriad of economic and social reasons, these systems are very slow to change.

Environmental orthodoxy holds that the solution to climate change is within our grasp—all that is lacking is political will to deploy easily available, off-the-shelf technologies. If we could simply silence the coal companies, our problems would be solved. I heard a prominent congressman remark last month that, in the future, we would look back on climate as a simpler challenge than the conventional air pollution controls enacted in the 1990 Clean Air Act amendments.

With all due respect, that is dangerous nonsense. Decarbonization of the global economy and stabilization of greenhouse gases in the atmosphere at safe levels will require extraordinary technological advances and a host of economic and social transformations that extend far beyond anything we have ever known in the history of environmental protection.

A few minutes ago I said that geoengineering would be the largest, longest, and most complex engineering effort in human history. Let me add: *Much the same might be said for mitigation*.

I believe we can, and must, decarbonize the global economy—but it will not happen quickly. It probably needs to be done by mid-century, if not sooner—and yet I fear it may not happen until the turn of the century, if then. That is not an argument against mitigation, it is an argument for realism in our expectations.

We could conclude that mitigation has "failed" and that "therefore" we need geoengineering—you hear that framing often—but that would be a mistake. I prefer to say, *mitigation must succeed*—but we cannot afford to be naïve about how quickly it is proceeding, and consequently, what the composition of the Earth's atmosphere is *likely* to be in the decades ahead.

That's as far as policy analysis will take us. So let me turn to climate science briefly, and review what we know about the *possible* effects of the changes in atmospheric composition that are underway.

We know that significant warming—perhaps more than 2 degrees C.—is already "locked in" by past and already-inevitable emissions. There are large uncertainties in our estimates of the future—but the bottom-line reality is inescapable:

In every plausible scenario for future emissions, regardless of the success of mitigation efforts, global temperatures will continue to increase throughout the twenty-first century. The only question is how much, how quickly, and to what effect.

Quite simply, we are on a warming path, and absent geoengineering efforts to cool the planet and remove greenhouse gases from the atmosphere, there is no going back. Mitigation efforts, of course, will still influence both the rate and ultimate extent of warming, but *they cannot cool the planet* in this century.

There are two reasons for that: First, because carbon dioxide is unique among pollutants in two fundamental respects: Its extraordinary *abundance*, and *persistence*. Carbon dioxide is uniquely intertwined with the global economy, and it lasts for centuries. The carbon dioxide emitted by the first steam engine is still contributing to climate change today. So when we stop emitting, we haven't even come close to solving the problem: the carbon dioxide is still there, and it is quite likely that we will need to find ways to either remove it from the atmosphere or counteract its worst effects, or both.

And once set upon a path of warming, it's not easy to turn back quickly—there's a tremendous amount of inertia in the system. Having warmed the world's oceans and loaded them, and our atmosphere, with carbon dioxide, things won't just turn around once we eliminate emissions. Disruptions to the global climate, once set in motion, will not be reversed by natural processes on timescales that are relevant to humanity. For centuries after atmospheric concentrations of greenhouse gases peak, their effects will be felt.

What does that mean for the future? We cannot know—but there is certainly cause for great concern. While there remains significant uncertainty regarding the pace, severity, and distribution of climate change, and its ultimate effects, the picture drawn by climate science today is increasingly grim.

I'm not a climate scientist, but I am struck by what I read in the literature:

The Earth's systems are complex and poorly understood. We simply lack sufficient observational data to make certain judgments of many critical processes.

But we do know that paleoclimate data show major and sometimes swift fluctuations in the earth's climate, some of which can be explained, and some of which remain frighteningly mysterious. The data also suggests that atmospheric carbon dioxide concentrations are higher now than they have been in hundreds of thousand years.

How warm will the future be? This is where it gets difficult—but there's still a simple bottom-line: It's likely to be quite warm, and we can't simply dismiss the risk of truly catastrophic scenarios.

The most probable temperature increases fall within the range of 2 to 4.5^{o} C. That in itself is plenty to be concerned about, particularly at the upper end of that range.

But far more worrisome is the picture when you consider the distributional probabilities, which cover the uncertainties associated with climate change. It's possible warming will fall *either* below or above the expected range—but, unfortunately, there is a greater probability that temperatures will be *significantly higher* than the 2-to-4.5 degree range, than it is that they will be lower.

This probability differential is what Harvard economist Martin Weitzman and others have famously characterized as the "fat tail" of risk. Simply put, there is a risk—relatively small but far from trivial—that the future will be very, very warm.

And when you consider the ways climate change will exacerbate other social and environmental stresses in already-unstable parts of the world, it's not hard to see how the consequences could be catastrophic—droughts, starvation, flooding, disease, wars; the litany of possible horrors is bounded only by one's imagination.

I think there are at least two major questions we should consider, therefore: First, how much should we be concerned about the risk of a low probability/high impact event?

And secondly, even short of such extreme scenarios, how confident are we that the world could ride out the effects of, say, 3 or 4 degrees of warming, which is not at all improbable, without fairly disastrous consequences?

Given the precarious condition of many developing nations, the myriad ways in which climate disruptions can spur conflict, and the enhanced appreciation we have now for the hazards of failed states, I do not think we can afford to be sanguine about these scenarios.

We should take these risks seriously—and the only possible way of managing them is through a geoengineering research program designed to complement mitigation and adaptation efforts. Should we also redouble our effort at mitigation, in light of those risks? Yes—but understand that doing so may not be enough.

Right now our portfolio of climate policies includes three options: mitigation, adaptation, and suffering. We can mix and match between them, but we don't get to choose—or accurately anticipate—the total burden. Personally, I would sleep better at night if our first choices were some combination of mitigation, adaptation, and geoengineering, because done well, I think it's at least conceivable that geoengineering could go a long way toward taking substantial suffering off the table.

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I have emphasized that, absent more reliable information about geoengineering's true capabilities and limitations, we can only speculate about what role it might play in climate policy in the future. But a few minutes of speculation might be worthwhile.

Risk is central to the climate policy problem, and the core of the rational for research on geoengineering. We shouldn't research geoengineering *despite* the uncertainties about the future effects of climate change, we should research it *because* of them.

But what about the risks of geoengineering?

Regarding the dangers of deployment, I think it's too soon to say much. Modeling indicates that a high-CO_2 world with geoengineering would have a climate much closer to today's than it would absent geoengineering, which superficially suggests that risks could be reduced; but fundamentally, we don't yet know what geoengineering methods would be used, or how well they can be designed to reduce the risks of unintended consequences. So debating ozone depletion or precipitation disruption or cost estimates is interesting but at the same time somewhat pointless; from a policy standpoint, we need to know much more before we can make meaningful judgments about those matters.

But there is one risk to conducting research itself that deserves discussion, the so-called "moral hazard"—the fear that greater consideration of geoengineering's feasibility might lead people to conclude that it is a viable alternative to mitigation, and consequently, to try less to reduce emissions—if that's even possible.

Moral hazards are real—and sometimes hard to avoid. We've heard about them most recently in the debate over bailouts for "too big to fail" banks. But in the climate context, I find the argument flawed on several levels:

It has always struck me as implausible that any national leader would argue that geoengineering offers a safe alternative to emissions reductions—or that the American people would go along with the idea. Such a claim would require an extraordinary—indeed, I would say unobtainable—level of confidence in an unproven and manifestly imperfect technology.

In fact, I have long believed that most people, when told about geoengineering, would be more inclined to support greater mitigation, not less, thinking: *If such extreme measures are really being contemplated, surely we ought to be more aggressive in our pursuit of other solutions.*

Imagine, for instance, you were unable to control a potentially serious medical condition through diet and exercise—you want to, but lack the willpower or the workout equipment you need—so after a while, your physician prescribes a medication that carries the risk of serious side-effects while only treating some of your underlying condition. Wouldn't you redouble your commitment to diet and exercise?

In fact, focus groups held in England as part of a study commissioned by the Royal Society seem to confirm that hypothesis, with participants—*particularly self-identified climate skeptics*—reporting that consideration of geoengineering would be a *galvanizing factor*, not a cause for complacency, on their part.

We have very limited public opinion data on this question in the United States, but what we have implicitly supports the Royal Society findings: Americans are interested in geoengineering research, but they do not see it an alternative to emissions reductions.

A final point on this question: Let's be clear, Pandora's box has already been opened; people know about this idea, and research is underway or being planned in Europe, the United Kingdom, Russia, and China. That means that the moral hazard already exists—as well as the practical hazard of incompetent geoengineering. The question is whether further research in the field might actually reduce those risks by revealing the true limitations of these techniques.

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There is one more important reason to support research on geoengineering that deserves consideration.

For more than a hundred years, a debate has raged in environmental circles between preservationists, who come from the Henry Thoreau-John Muir tradition, and conservationists, those following the Gifford Pinchot model of ecosystem management that inspired the US Forest Service in its earliest days.

Personally, I come at these issues from the preservationist perspective, having spent most of my twenties living and working in some of America's greatest wilderness areas.
I think in many respects, the preservationist ethic rightly remains the bedrock of our approach to many environmental issues, particularly with respect to pollutants. In countless ways, the general sentiment that guides our actions is "Don't manage environmental risks, eliminate them. Don't try to second-guess Mother Nature; just protect her."

My message today, then is a serious one. When it comes to climate change, we can no longer afford to cling solely to the preservationist perspective. Today, the goal of climate policy is to preserve the past, when reality demands we turn to face the future and accept the responsibilities that lie ahead.

To use another analogy: I have heard some people describe the global climate as a car speeding down a foggy road, out of control and heading toward a cliff we cannot see. If you accept that analogy, I would say humanity has been crouched under the dashboard, trying to reach brake pedals that don't seem to work.

Geoengineering invites us to sit up, look ahead, and realize that *there is a steering wheel*, even if it's an imperfect one. That isn't a solution to the climate problem—but it is a different posture in the seat, and that may make all the difference.

I should note also that, implicit in that analogy, is a fundamental truth that people should not overlook: We *are* in the driver's seat with the global climate already—with our hands off the wheel. We are currently engaged in a massive, unintentional, and uncontrolled climate engineering experiment, hurtling into the future and trusting that it will be all right, despite mounting evidence to the contrary.

We are far from knowing which climate engineering techniques might work, and whether we will really need them—but if we are to ever have the opportunity to do so safely, we need to begin to make plans for it now. The very idea itself invites us to take a broader view of the climate challenge, and to accept responsibility for what we are doing to the planet.

As the evidence mounts that emissions reductions alone may be insufficient to protect us from serious harm, we must accept that we can't afford to ignore the need to consider other tools, such as solar radiation management, or biological or chemical sequestration of carbon dioxide.

We are told that one reason climate engineering is impractical is that it offers the prospect of a global thermostat, but no framework for deciding where to set it. How can we expect billions of people to agree? But the point is, we should think about that question, and its many variations, whether or not we have the geoengineering option; it underlies the landscape of climate policy, but geoengineering brings it front-and-center.

Geoengineering also highlights the profound gaps in our understanding of climate science—and offers some insights that may contribute to closing them. Geoengineering asks us to understanding the totality of the human influence on the climate and global ecosystems—and all the ways we can change it. As climate scientist Tim Lenton has remarked, "The climate is complicated. Why should we try to control it using just one knob?"

To many, the idea of controlling the climate at all may sound arrogant in the extreme. I understand that reaction, of course, but I would argue it is *humility* that directs our attention to climate engineering. In contrast, a firm confidence in the adequacy of mitigation and adaptation measures is the mark of arrogance, ignorance, or delusion. We need to accept that we do not yet know what we've done to the climate—and what it might take to protect ourselves in the future from the consequences of our actions today.

Critics accuse proponents of climate engineering research such as myself of seeking a "quick fix" for the climate problem. Nothing could be further from the truth. Geoengineering is not a solution, and climate is not a problem that can be solved, at least not within our lifetimes.

Climate change is a condition to be managed, one that humanity will wrestle with for generations; geoengineering potentially offers the prospect of a group of new tools to help manage it, adding to a sparse and so-far seemingly inadequate policy toolbox.

That is the key significance of this idea: Geoengineering, in all its forms, challenges us to start taking the climate seriously enough to seek to understand all of its component parts, how they interact with each other, the many ways in which we influence them, and how we might alter those interactions to produce better outcomes. To me, that is the first requirement of a serious, comprehensive perspective on the challenge of global climate change.

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In some sense, human history can be seen as a never-ending struggle to acquire knowledge and use it wisely, to free ourselves from the shackles of ignorance and fear and irrational inhibitions. Geoengineering is another unique chapter in that long story, and the fate of the planet may rest upon our ability to think clearly about the unthinkable.

I stand here now, squinting at my speech through glasses that do not fully correct my vision problems because on some level, I just cannot imagine asking someone to slice my eyeballs open with a laser and insert small, crescent-shaped discs of plastic that could give me 20-20 vision or better.

I'm probably foolish to feel that way—I'm at some risk for blindness, or at least a cornea transplant, by leaving my condition untreated—and my new year's resolution for 2011 will be to reconsider, because sometimes the unthinkable is just what you need to do.

We will ignore the need for geoengineering research if we simply dismiss it as unthinkable madness—but future generations may deeply regret our lack of foresight if we do.

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