THE U.S. CAN'T GO IT ALONE ON SOLAR GEOENGINEERING

Smaller democracies should take a role in shaping solar geoengineering research and governance, say David Keith and Peter Irvine. Without them the challenges that solar geoengineering poses will be harder to tackle and the risks of mistrust and misuse will be greater.

By Peter Irvine and David Keith

The world must do more to tackle climate change. Rich nations who are responsible for most historical emissions must go farther and work faster than poor nations who will suffer the most. In this respect, the UK is a world-leader. It signed the first nationally binding emissions cuts into law in 2008 and is now half-way to achieving its net zero target, with greenhouse gas emissions down 50% since 1990.[1] The UK also made heavy investments in climate science over decades, supporting world-leading work at the Met Office and universities, and has supported clean energy and carbon removal research. It has also developed official capacity such as the independent Committee on Climate Change that advises the government on how to meet its climate pledges and holds the government to account.

However, the UK has abandoned its early leadership on a novel and potentially revolutionary climate policy option: solar geoengineering. It is past time for the UK and mid-sized democracies like it to re-engage.

Solar geoengineering describes a set of methods (see the box below for details) that could offset the heat-trapping effect of greenhouses gasses by reflecting away some sunlight or, in the case of cirrus thining, by making it a bit easier for heat to escape into space.This idea is also called solar climate intervention, and solar radiation modification. Whatever it's called, it's perhaps best defined in relation to other ways of managing climate risk. It is one of four toolboxes:

- Decarbonisation: transitioning to carbon-free energy to eliminate the greenhouse gas emissions that drive climate change;
- Carbon removal: actively removing CO_2 from the atmosphere to manage the burden of historical emissons and to offset hard to eliminate emissions;
- Adaptation: preparing societies and ecosystems, where possible, to better cope with the hazards of a changing climate;
- Solar geoengineering: actively modifying the Earth's energy budget with the goal of ameliorating climate hazards due to long-lived greenhouse gases.

Climate change poses two challenges: tackling the accumulation of long-lived greenhouse gases that drive climate change and coping with the consequences of the changing climate. Decarbonisation is essential, but even when emissions are eliminated humanity will only have prevented the problem getting worse. Carbon removal complements and extends this effort, making it possible for future generations to reverse the build-up of CO_2, returning the climate towards its pre-industrial state. To meet the second challenge, adaptation will be essential but many of the impacts of climate change will be beyond the adaptive capacity of some societies and ecosystems meaning there will be a significant amount of

loss and damage. Solar geoengineering is no substitute for decarbonisation and carbon removal; instead it offers the possibility of reducing the amount of climate change during the period when greenhouse gases are highest, reducing the amount of human suffering and ecological damage.

Solar geoengineering may sound implausible, and an uncertain and risky response to climate change. Yet a growing number of climate scientists and environmentalists now take this prospect seriously. This is, in part, because even if countries follow through on their pledges for emissions cuts made in Paris in 2015, we seem on track to blow through both the aspirational 1.5 and 2.0 °C temperature targets before mid-century.[2]

While solar geoengineering might enable the world to avoid passing the 1.5 °C threshold this is not a sound reason for considering it. Despite some of the rhetoric, there is no scientific consensus that there is a sharp threshold at 1.5 or 2.0°C, below which climate risks are manageable and beyond which they are not. Instead, what the science tells us is that the risks of climate change grow with temperatures. The more carbon we emit, the warmer the planet gets, and the worse the risks.

The case for responsible research into solar geoengineering

The more sound basis for considering solar geoengineering is simply that there is a growing body of evidence that strongly suggests some solar geoengineering technologies could, if used appropriately, substantially reduce important climate hazards over most of the world, with physical harms or risks that are small compared to the aggregated benefits of reduced climate impacts.[3] While over a hundred scientific studies into solar geoengineering have been published so far, it is too early to decide to develop and deploy it or to rule it out. The uncertainty is far too large. However, the evidence of solar geoengineering's potential to reduce human and ecological impacts is sufficiently strong to justify launching a substantial research effort and sustained policy attention.

In 2009, the UK's Royal Society published the world's first report to address solar geoengineering.[4] The Royal Society concluded that this approach might offer an opportunity to reduce climate risks, though warned of substantial uncertainties, including that it might pose a considerable threat to the international order as individual nations could have the power to change the global climate. The Royal Society recommended £100 million be spent over ten years researching solar geoengineering and carbon removal (which was equally novel at the time), and in response the UK launched a much more modest but still world-first state-funded research effort into the topic. However, by 2014 the UK had abandoned all research into solar geoengineering, around the same time that it also abandoned its carbon capture competition amid severe fiscal constraints (the latter has since been re-adopted as a strategic priority).

The UK recently published an official view that addresses solar geoengineering, also called "Solar Radiation Management" (SRM), that states: "The UK Government has commissioned research into the effects of SRM on climate,

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and monitors research in this area."[5] No rationale is provided for abandoning research, however the previous version of the document said: "The UK Government has commissioned research into the effects of SRM on climate, which showed that SRM deployment would produce changes in rainfall patterns and amounts. This would be likely to lead to 'winners' and 'losers', with some regions suffering detrimental impacts."

Why was this reasoning dropped from the latest version? Perhaps because it is a poor argument against research. What important policies have only winners? Or perhaps, it is because the claim that SRM will necessarily produce sharp inequalities looks weaker as the science develops. Our 2019[6] and 2020[7] papers showed that if deployed alongside emissions cuts to halve future warming, solar geoengineering could substantially reduce the effects of climate change where they are greatest and only slightly worsen some of the effects in the least-affected regions. Furthermore, it is not just a couple of papers that come to these conclusions. Hundreds of climate model studies all point to the same conclusions: solar geoengineering is feasible and if used in moderation as a complement to emissions cuts could substantially reduce the overall risks of climate change.[8]

The need for responsible research and governance

Research on solar geoengineering is at an early stage. We may be wrong about its potential and impacts. Deploying solar geoengineering hastily and in ignorance could very well have disastrous environmental impacts. Despite these uncertainties and risks, the unique potential of solar geoengineering to immediately halt or even reverse global warming will be a temptation to world leaders facing growing demands for immediate relief from the impacts of climate change. Kim Stanley Robinson's, Ministry for the Future, paints a compelling picture of such a scenario. After a deadly heatwave in India the Indian government unilaterally deploys stratospheric aerosol geoengineering. If such an unbearable climate disaster occurs in a powerful nation and worse is expected, it may be hard to dissuade them from taking matters into their own hands.

Robust scientific scrutiny, multilateral collaboration, and transparent deliberations about how to govern solar geoengineering are needed to forestall the risk of desperate, ill-informed, unilateral deployment. These same actions are also what is needed to determine whether solar geoengineering could be developed and done so in a way that furthers the global public interest. While tentative research efforts into solar geoengineering have been made by the UK, China, US and across Europe in the past decade and we have seen the very beginnings of a discussion of this issue in international fora, there is a leadership vacuum on this topic.

With the release of the National Academy of Sciences (NAS) report that recommends $100 - $200 million be spent on a major research effort into solar geoengineering, the US is set to fill this leadership vacuum. The NAS report distils the science, social science, and governance discussion on solar geoengineering to make a set of research and governance recommendations that the new US administration would be wise to follow.[9]

Solar geoengineering might pose a considerable threat to the international order as individual nations could have the power to change the global climate.

First, the NAS report makes clear that while solar geoengineering potentially offers a novel strategy for reducing climate risks, it is not a substitute for reducing greenhouse gas emissions. The research agenda that the NAS lays out strikes a balance by not only addressing the impacts and technical dimensions of solar geoengineering, but also giving equal weight to considering the context and goals for research, and to the social dimensions. The report recognises that solar geoengineering, even at the research stage, raises serious public and governance concerns, hence it recommends that 20% of funds be spent on promoting the development of robust national and international governance for research and for conducting public engagement exercises.

The NAS also recommends a set of research governance principles be integrated into the research effort from its inception, including, for example, making sure all results are publicly available, maintaining a public registry of research and ensuring that off-ramps are in place to end research if needed. While the report advises against developing the technology required for deployment, it recommends field experiments for advancing understanding that cannot be achieved by other means. It also provides some recommendations to ensure that such activities do not have adverse environmental impacts.

The central problems of solar geoengineering are not developing the technology itself. Rather they are the problems of building trust in scientific predictions of benefits and risks, and in building an international system of governance that has sufficient political legitimacy so that decisions about deployment are stable in the face of inevitable international disagreements.

The central problems are, in short, geopolitics and international governance. And it is implausible that a US-dominated effort will succeed in resolving them. The USA's history of unilateral, or near-unilateral, military action and its hegemonic position will generate fears that it will develop and deploy solar geoengineering in its own interests and to the potential detriment of others. The instability of US politics, made all too evident under the Trump presidency, has further weakened US credibility.

It would be better if research and the development of governance regimes were internationalised from the start. We suggest that smaller developed democracies, with strong records on climate action, work together with demoncracies in developing economies that are most vulnerable to climate change. Such a coalition, with a strong commitment to emissions cuts and just climate outcomes, would have the

scientific capacity to assess solar geoengineering and the legitimacy to develop an equitable framework for making decisions about potential deployment. As an internationally respected leader on climate action with world-leading climate research, and outsized political influence, the UK is well-positioned to take a leading role in such a coalition. Its position at the heart of climate diplomacy in 2021 also lends the UK the ability to make faster progress than most.

Three key challenges of solar geoengineering

Some will argue that solar geoengineering is too risky, that we already know enough about it to ban it forever and abandon research.[10] Before making our policy recommendations we address three concerns about solar geoengineering that some believe justify abandoning research: moral hazard, termination, and unilateralism.

Emissions reductions are essential to bringing climate change to a halt. Nothing about solar geoengineering changes that essential fact. But societies and ecosystems are already facing serious risks which will worsen substantially before emissions are brought to zero. Furthermore, eliminating emissions just stops the problem getting worse. To reduce climate hazards, it will be necessary to actively remove carbon from the atmosphere, a process that will be slow and expensive. The threat posed by future climate-related risks motivates us to cut emissions cut as well as to explore solar geoengineering.

1. An excuse for inaction?

Whether or not to bring solar geoengineering into climate policy poses something of a catch-22. If solar geoengineering becomes recognised as an effective means of reducing the risks of climate change then it may sap the willingness of societies to make the difficult transition to a zero-carbon world as these risks motivate the need for emissions cuts in the first place. If that happens then we may end up with greater emissions and in turn greater risks of climate change. The more effective and convenient that solar geoengineering is seen to be, the greater the potential threat.

For those who have been following the climate debate for some time this may sound familiar. The climate community faced a similar challenge with adaptation back in the 90s.[11] To discuss ideas to minimise the impacts of climate change through adaptation, e.g., building seawalls, adopting new agricultural practices and improving the built environment, seemed to be to downplay the risks of climate change, and there were worries it would sap the willingness for difficult emissions cuts. However, adaptation is now a core part of climate policy and developing policies for adapting to the inevitable impacts of climate change did not derail climate policy, it made it serve the most vulnerable better.

If the research on solar geoengineering's potential consequences holds up, then it could play an important role in managing the otherwise unavoidable near-term climate risks that will occur on the way to net zero CO_2 emissions and peak temperatures. To have the greatest positive impact,

solar geoengineering would need to be understood as a complementary, additive measure to be incorporated alongside emissions cuts, carbon removal, and adaptation, rather than an alternative to these measures.

However, we should not be naïve about how solar geoengineering could shift the debate on climate change. There will be a temptation to relax efforts to cut emissions, or not to strengthen them as much, if the costs of emissions cuts are deemed too high or politically costly (see, for example, the 'Gilet Jaunes' movement in France). Furthermore, there will be actors, in the fossil fuel industry and elsewhere, who have a vested interest in the status quo and may promote solar geoengineering as a substitute for strengthened emissions policies.

This concern about solar geoengineering, often referred to as moral hazard or mitigation deterrence, is the most widely cited and discussed concern about the idea. There is some evidence from public perception studies that when the public is presented with the idea of solar geoengineering, it raises their concern about climate change and their willingness to support emissions cuts, i.e., it has the opposite effect from the one feared.[12] However, such tests may not give a good indication of how the idea will be viewed if and when powerful industry, media and political interests begin pushing a narrative that presents solar geoengineering as a technological get-out-of-jail-free card.

Is concern about moral hazard sufficient reason to abandon research? Our answer is no, but we agree that some research should be restricted. Economic decision analyses that assume rational actors find that research is never bad (assuming the costs are negligible), because the decision-maker can simply decide not to use whatever new knowledge is generated. In a world with irrational decision-makers in frequent conflict—the world we live in—some things are better left unknown, such as a recipe for easily synthesizing smallpox.[13] But the bar for ending research should be high and given the evidence that some forms of solar geoengineering could have enormous benefits for the world's poorest,[14] and the lack of plausible pathways for weaponisation, we don't see how concerns about moral hazard come close to justifying a moratorium on research. However, concern about moral hazard is a good reason to develop governance structures that can counter efforts by self-interested actors (e.g. fossil fuel interests) to promote solar geoengineering as an alternative to emissions cuts.

2. The risk of unilateral action

Stratospheric aerosol geoengineering is a proposal to create a global aerosol layer to scatter light and cool the Earth and is arguably the leading solar geoengineering proposal. Research indicates that stratospheric aerosol geoengineering would be feasible and cheap to implement with new high-flying jets, with the latest estimates placing it as low as $10-30 Billion per year per degree-celsius avoided.[15] The barrier to entry is therefore low enough that several countries could afford to develop and deploy it, raising the prospect of one nation pursuing a unilateral policy of climate intervention.

While it is perfectly possible for one nation to deploy stratospheric aerosol geoengineering in their narrow self-interest, there are good reasons to believe this scenario is unlikely. Firstly, stratospheric aerosol geoengineering is an inherently global intervention. The stratospheric circulation quickly spreads any injected particles across all longitudes and then towards the poles, allowing only a limited degree of control over the resultant pattern of cooling, mostly limited to determining whether the tropics or high latitudes are cooled more. While it is possible to only deploy stratospheric aerosol geoengineering over a single hemisphere, doing so would radically alter tropical hydrology with potentially disastrous consequences for the region.[16] The benefits of pursuing such a selfish hemispheric strategy would be trivial (it would halve the relatively small direct costs of deployment), whereas the

resistance to be expected from affected nations, in the form of political pressure, sanctions or military action, would seem certain to be overwhelming even for a superpower.

Given the potential push-back, even the most self-interested nation would have an incentive to pursue a stratospheric aerosol geoengineering strategy that avoided clear harms to other nations. Secondly, even if a nation committed to deploying stratospheric aerosol geoengineering, there is little reason to do so unilaterally. All nations are affected by climate change and all have agreed to limit warming, and so, assuming the science continues to suggest that stratospheric aerosol geoengineering could reduce the overall risks of climate change, it seems likely that a nation that wished to pursue deployment could gather a coalition to support this. Given the mutual interests in limiting global warming, and the limited degrees of freedom afforded to the deployer, there seems little to be lost by involving others in the choice of how to deploy and much to be gained by building a coalition, in terms of legitimacy and reduced push-back from other nations.

3. Termination shock and the long-term commitment to deployment

Another prominent concern about solar geoengineering is that as it only masks the warming effects of greenhouse gases, if deployment were suddenly stopped, temperatures would rapidly recover to where they would have been without solar geoengineering. This would lead to a rate of warming in the following years that would be greater than what would have been seen under climate change. Some have argued that this implies that once solar geoengineering is started, we would be locked into deploying it indefinitely, given the millennia it would take for atmospheric CO_2 concentrations to return to pre-industrial conditions.[17]

However, there are two possible off-ramps. First, solar geoengineering need not be deployed to keep temperatures constant indefinitely, it could be deployed to only slow the rate of warming, buying time for adaptation.[18] Alternatively, once deployed, it could be phased out gradually over the course of decades. Second, carbon dioxide removal (such as bioenergy and carbon capture and storage, which is championed by the British Government, among others) offers a means of driving CO_2 concentrations down such that the warming that solar geoengineering is offsetting is gradually eliminated. The two could be calibrated as complementary solutions.

If solar geoengineering is to make a substantial contribution to limiting global warming it will need to be deployed for many decades. This is not, however, a unique requirement. Humanity is not even more sharply dependent on maintaining a range of technologies, from electric power to the production of nitrogen fertilisers. Tackling anthropogenic climate change will take a long time: it will take decades to reach net zero emissions and for temperatures to peak, millennia for the carbon cycle to recover naturally or at least a century with the help of carbon dioxide removal, and sea-level rise is expected to only keep accelerating for the next few centuries. Anthropogenic greenhouse gas emissions will leave a legacy that future generations will be managing for centuries to come. The question is: could solar geoengineering play a useful role alongside other climate policies in managing this troubling legacy?

Solar geoengineering only masks the warming effect of greenhouse gases and so if something unexpectedly prevented its deployment then a rapid warming would follow, a risk known as 'termination shock'. Some argue that it would be dangerous to develop a global system that must be maintained for decades, pointing to the turmoil of the 20th century. However, it seems relatively easy to forestall all but the most apocalyptic threats to maintaining this system.[19]

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First, the stratospheric aerosol geoengineering deployment system is inherently robust: tens of aircraft operating from multiple airbases would be hard to disrupt and any disruption must persist for many months before it would have a noticeable climate impact given the fact that the aerosols persist in the stratosphere for a year or more before falling out. Those aircraft need not operate globally to spread aerosols; atmospheric circulation will do that for them. With appropriate back-ups and defences, it would take a global superpower or world-shaking calamity to interrupt deployment.

Second, all nations would have a vested interest in avoiding termination shock and so even if some superpower or coalition demanded solar geoengineering end, they would be much more likely to demand a slow phase-out rather than a sudden termination of activities. Those who want to see dams taken down do not want them dynamited when full, they want them drained and dismantled. The potential for a termination shock can be relatively easily avoided but it places a burden of long-term management on future generations.

A path forward

The geopolitics of solar geoengineering are not yet apparent. While discussions have reached heads of state and preparatory meetings at the UN Security Council, nations have not articulated clear positions. When the topic is discussed at meetings under the UN Framework Convention on Climate Change (UNFCCC), the discussions are generally kept out of the public spotlight.

The behind-the-scenes interest combined with the current lack of clear positions from the major powers provides

an opportunity for a loose coalition of small democracies to shape the agenda for research and governance.

What would this leadership look like? The priorities today are to understand, collaborate and debate so that a foundation of knowledge and trust can support later decisions on whether to develop and deploy solar geoengineering. For the UK this means making significant investments in research at home, perhaps through the forthcoming Advanced Research and Invention Agency (ARIA); supporting international research collaborations, especially with developing world, perhaps through the Global Challenges Research Fund; and leading efforts to develop an international governance framework for solar geoengineering. Without strong leadership on solar geoengineering, there is a chance that we may either miss a great opportunity to reduce the risks of climate change or see risky, unilateral actions that lead to catastrophic outcomes.

The scientific research and technological development required to improve understanding of solar geoengineering's benefits and risks is not inherently expensive. This means that comparatively small or poor countries could, in principle, play a significant role.

The scale of funds required is very different than the scale of funds required to develop technologies for emissions reductions, let alone to deploy them. As a rough guide the total amount the world now spends on clean energy deployment is roughly $300 billion per year, and it needs to be spending over $1 trillion per year (roughly 1% of GDP) to reduce carbon emissions at a reasonable pace. The cost of clean energy R&D is hard to estimate, but one could possibly argue that it should be several percent of the cost of energy deployment, so many tens of billions of dollars per year.[20] In contrast, the total funding required for a serious solar geoengineering R&D effort might never exceed a few hundred million dollars per year globally, and it would start much smaller.

This means, that at least in principle, a coalition of smaller democracies including a mixture of high-income and low-income countries could play an important role in shaping geoengineering research and the development of international governance. This could start with developing a broad collaborative research programme managed by memoranda of understanding between science funding agencies, articulating principles for research governance such as data sharing, a registry of research and experiments, and principles of open access, transparency, and non-commerciality.

Developing non-binding principles for collaborative research on a non-commercial technology is a small and comparatively easy step. But it is not insignificant, as it could build a network of government officials and civil society that could begin to work on the hard problems: developing the foundation of international governance of deployment—including decisions not to deploy—that could be widely respected as legitimate.

No such loose arrangement can avoid the geopolitical realties. If China and the US, for example, develop clearly aligned interests they could, no doubt, impose their decision. But given the great powers have yet to develop hard positions on this issue there is space for a governance structure to be advanced by a representative set of small democracies that could define the terms of engagement.

The UK led the world on solar geoengineering but then abdicated its leadership perhaps out fear of controversy. This is a mistake. Decisions about challenging technologies are best made with knowledge and broad engagement, not ignorance and secrecy. It is time for the UK to end its silence on this topic and to lead a responsible international debate on solar geoengineering.

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Notes

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