Startups and Solar Geoengineering (Alt title: What's Wrong with Cooling Credits)

Britta Clark

Early draft—Please do not cite or circulate without permission

Prepared for 2025 Harvard/RFF SRM Workshop

Feedback warmly welcome brittaclark@g.harvard.edu

In 2023, a start-up called Make Sunsets began releasing aerosols into the upper atmosphere. For a mere ten dollars, founders Luke Iseman and Andrew Song claim that they will personally release 1 g of SO_2 into the stratosphere. The particles will reflect a small amount of incoming sunlight back into space, before falling back down to Earth in one to two years.

Make Sunset's actions elicited widespread condemnation from the climate and geoengineering research and policy communities.[1] Some of this criticism is straightforward: many remain categorically opposed to solar geoengineering research or (even small-scale) deployment regardless of who controls it (Biermann et al. 2022; VanDeveer et al. 2024). However, even those researchers and commentators who have expressed qualified *support* for solar geoengineering research in academic settings strongly denounced this new private venture.

Since Make Sunsets began operations, others have followed suit. Janos Pastor, former UN Assistant Secretary-General for Climate Change, was recently hired as a consultant for Stardust Solutions, another solar geoengineering start-up that aims to develop an alternative injection material to sulfates. Together, Make Sunsets and Stardust have garnered nearly USD 16 million in venture capital funding. The number of patents related to solar geoengineering has been steadily increasing (Ramos and Santos 2025). And students in a Bill Gates-funded 'Climate Ventures' class described being 'inspired' by Iseman and Song and are pitching their own alternatives.[2]

We thus find ourselves in what I take to be an uneasy situation. Initial condemnation of solar geoengineering start-ups was strong enough to, in my estimation, subtly stifle debate on the topic of private involvement in these technologies: the activities of Make Sunsets, especially, were seen as so *obviously* foolish that there was little sustained effort to explain and debate the exact nature of the foolishness.[3] Yet these ventures are forging ahead, perhaps even buoyed by the widespread criticism.

The central aim of the below reflections is to make some progress in explaining *why* we should be concerned about a market-based approach to solar geoengineering. I will focus on the

[1] For a sampling, see: https://www.nytimes.com/2024/09/25/climate/rogue-solar-geoengineering.html, https://www.npr.org/2024/04/21/1244357506/earth-day-solar-geoengineering-climate-make-sunsets-stardust;

[2] Personal communications with 'Project Sunshade.' These communications were part of the initial motivation for this paper. In an interview with students in the Climate Ventures class, who have since raised $250,000 to fund their own solar geoengineering start up, I felt compelled to argue against their approach. Yet upon reflection, I found myself unconvinced by many of the arguments I presented.

[3] I'll mention a few notable exceptions in what follows.

model of buying and selling 'cooling credits.'[4] My starting point is that there is indeed something (or multiple things) to be worried about. Still, I try to remain somewhat open to being wrong about this.[5]

I proceed as follows. First, I examine a series of distinct arguments against the cooling credits model that are frequently referenced but seldom fully articulated. Two of these arguments I find unpersuasive. Another argument shows that markets in cooling credits are problematic *now,* but doesn't make a general case against markets in cooling credits once certain conditions are met.

Then, I turn to what I take to be the most plausible basis for an argument against the cooling credit model: the idea that reflecting sunlight and reducing emissions operate differently on the climate system. This observation, if supplemented, can yield a case against markets in cooling credits, but only in the *absence* of wide scale decarbonization policy.

The more general message of this paper is a call for clarity from the solar geoengineering community regarding *why* a market in cooling credits is misguided. Considering the trajectory of climate policy, where many of the most popular proposals involve market-based instruments, it is worth it to be clear about what, if anything, sets the case of solar geoengineering apart. Moreover, as we'll see, considering questions about the normative status of 'cooling credits' leads us quickly to deeper questions about how to think about the relationship between new technologies and the speed at which we should aim to reduce emissions.

Bad Business

It's tempting to think that it would be a waste of time to build a normative case against the idea of cooling credits. The concept of such markets is gimmick, based on a business model that will never generate demand. After all, solar geoengineering appears to have the qualities of a 'public good,' and public goods are typically *under-provisioned* by the market.[6] It's hard to imagine a vibrant market in clean outdoor air, because the purchaser of said air would be unable to exclude anyone else from enjoying the benefit of what they've paid for. Moreover, my consumption of clean outdoor air does not preclude or limit your consumption. Cooling credits appear to have a similar structure.[7] Furthermore, regardless of the status of geoengineering as a public good, it is doubtful that an individual or even a group of consumers would experience any climatic benefit from their own purchase of cooling credits. Perhaps a few do-gooders would be

[4] One might also object to private involvement in the development of solar geoengineering technologies (a la Stardust Solutions). My sense is that it is worth it to treat different kinds of private involvement separately, for different forms of private involvement may be subject to different objections (or lack thereof).

[5] Methodologically, how this openness shows up is that I try to avoid (what is for me the tempting inference) that any argument that commends for-profit solar geoengineering research or deployment must have gone off-track. The impermissibility or wrongness of for-profit solar geoengineering schemes is something I am looking to *argue for,* not a fixed point in my reasoning that I am merely trying to *explain.*

[6] The standard definition of public goods does not imply that public goods are good in the normative sense. Rather, a good is a public good if the good is non-rivalrous and non-excludable. Though the textbook view is that public goods will be under provisioned by the market, several economists have argued that market-provision of public goods remains superior to state-supplied public goods. See Cowen (2018).

[7] Whether solar geoengineering is a public good in the standard sense will depend on what exactly the 'product' is. The actual release of aerosols is excludable, but increased reflectivity is not. For an argument that geoengineering does *not* count as a public good, see Gardiner (2014). For the opposite view, see Morrow (2014).

inclined to offset the radiative forcing of some of their airline travel, but it's hard to see where broader demand for this product would come from.

Notice, though, that the above concerns *also* apply to markets in carbon dioxide removal (CDR). After all, the current CDR market is a voluntary one: companies like Microsoft are pre-purchasing removals with the knowledge that their purchase, once delivered, will likely have an imperceptible impact on atmospheric CO_2 concentrations. These companies, as well as the rapidly growing CDR industry itself, are betting on a future carbon price or cap-and-trade system, or perhaps just widespread consumer support.[8] CDR companies are also betting that, within such a system, they will be able to deliver removals at a lower cost than the carbon price or emissions reductions. And though I wouldn't take these bets myself, some suggest that CDR has a trillion-dollar market potential (Mckinsey Sustainability 2023).

Perhaps, then, those who argue against cooling credits based on the business case alone may be overlooking more imaginative possibilities over the longer term, especially as our scientific understanding of solar geoengineering develops. With proper institutional support, cooling credits could fare well on the voluntary market. Moreover, it's not inconceivable to picture cooling credits integrated into modified compliance markets. Presently, our carbon accounting systems, insofar as they exist, deal in CO_2. For instance, for around $1,000, direct air capture company Climeworks will remove one ton of CO_2 and store it permanently (Climeworks 2024).[9] But one can imagine a situation where the relevant system of accounting deals in 'temperature years', and environmental economists and like-minded policymakers argue vigorously for a 'heat tax' instead of a 'carbon tax.'[10] Indeed, as Kevin Surprise recently noted, SCS Global Services and First Environment, two companies that provide sustainability certifications, proposed precisely this idea (Surprise et al. 2025). 'Radiative forcing credits' would replace traditional carbon credits, thus bringing all forms of climate forcing under one neat system. Proponents of this system might emphasize how heat is the ultimate driver of climate impacts—we care about atmospheric CO_2 concentrations only insofar as they impact humans (and animals) via increased surface temperatures.[11]

Though not *essential* to the business case, ideally a market in cooling credits would avoid following in the footsteps of shady carbon offset markets, which historically have failed to result in net reductions in CO_2 (Trencher et al. 2024). This is a real concern at present, for it is unclear whether Make Sunsets' balloons are making it into the stratosphere. And, even if they are, the cooling effect is lost as soon as the aerosols fall to earth, after approximately one or maybe two years. Thus, for any individual or company to offset warming over the long term, the purchaser of a cooling credit would need to be enrolled in a subscription model, paying to re-inject reflective particles year after year. Just as the CDR market is continuing to develop so-called 'Monitoring, Verification, and Reporting' standards to ensure the integrity of removals, so too could a market in cooling credits, at least in theory, be held to strict standards.

---

[8] Companies could also be betting on future contracts with governments committed to removing legacy carbon. Alternatively, they could aim to build a product out of the captured CO_2 that is profitable on its own.

[9] Climeworks states that the captured CO_2 will be stored for over 10,000 years. Other forms of CDR will store CO_2 for different lengths of time. The standard for 'durable' (permanent) CDR is 1000 years.

[10] More precisely, such a system would probably deal in watt-year/m^2.

[11] Of course, the mechanism for avoiding climate impacts is different. More on this later on.

Moreover, aerosols cool almost immediately, so a cooling-credit system must control both the total injected amount and the tempo of injections. But there is precedent for managing this kind of problem: Grid operators, airlines, and irrigation authorities already use similar flow-smoothing tools. Borrowing from airline takeoff slot markets, a central authority could issue 15-minute 'injection slots.' Credits—each tied to a fixed time-stamp—could be traded but not rescheduled, preventing temperature swings. Real-time satellite monitoring could halt slot issuance if aerosol loading exceeds the planned path, while a small reserve of emergency slots could fill shortfalls.

My goal here isn't to fill in the details of the Make Sunsets business model, but rather to show that it is not as shaky as it may seem at first. Or, at the very least, the business case is not significantly *shakier* than the case for CDR, which has to this point received fairly widespread support from the climate policy community and investors alike.

In any case, objecting to the business model of cooling credits surely misses the point. Making a *business case* against some activity does not yield a *normative* case against that activity. And I take it that the condemnation of private involvement in solar geoengineering was not merely uproar regarding a poorly thought-out business plan. Nevertheless, I engage with the business case objection to show that those who oppose the sale and purchase of cooling credits can't *fall back* on a critique of the business model, nor can we rest assured that any attempts to create such a market will fail to get off the ground. And even if the business case against Make Sunsets is raised strategically—to persuade someone of a conclusion one embraces on ethical grounds—it's worth noting that the business case objection appears weak on its own terms.

Slows 'Legitimate' Research or Deployment

Another common concern is that the activity of buying and selling cooling credits will have a chilling effect on 'legitimate' solar geoengineering research or potential deployment. This argument appears to be problematically circular. We can't answer the question of why cooling credits are 'illegitimate' (or some cognate term) by pointing out that solar geoengineering will slow 'legitimate' solar geoengineering activities, as this assumes the very distinction between legitimate and illegitimate solar geoengineering that we were trying to explain. The proponent of the 'Slows Legitimate Research/Deployment' objection will need an independent account of why the idea of markets in cooling credits is problematic.

Moreover, the empirical claim this objection relies upon awaits further analysis: Solar geoengineering research seems to have proceeded unhindered since the launch of these companies. Indeed, interest and funding in solar geoengineering appear to have accelerated over the past few years. [12] One founder of Make Sunsets himself suggests that this is all part of the plan, claiming that "by starting to do it, hopefully, I've speeded up when this happens at scale by a couple years. Hopefully, people oppose the privatization of this. Hopefully, I can serve as this

[12] See https://srm360.org/funding-tracker/ for details. Of course, it's possible that research funding would have grown even *more* in the absence of start-up activity. But if the impact of start-ups on 'academic' solar geoengineering research is merely to make it so that academic research funding grows slightly more slowly than it otherwise would, then the strength of the 'Impacts on Legitimate Research' objection appears significantly weakened.

bogeyman" that pushes governments to step in and say, "We need to do this as responsible adults, because otherwise these startup guys are going to do it" (Miller 2024). Anyone defending the *Impacts on Legitimate Research/Deployment* objection should be prepared to provide an alternative story.

Governance First

A third objection to the 'cooling credits' model concerns the order of operations between research and governance. Some commentators have objected to the activities of these start-ups because they are engaging in 'rogue' geoengineering. As Sikina Jinnah puts it, "a couple of rogue tech bros taking action completely outside the scope of government authority or any public engagement are really embodying the nightmare of what folks think this could be" (Harris 2024).

As I read the objection here, it does not center on the harms involved in small-scale geoengineering, nor any characteristics of the market-based approach itself. Instead, the thought is that governance should precede (perhaps just some categories of) research, and certainly deployment. That contention, while important, does not provide an account of the type of governance we should aim for when it comes to geoengineering. Rather, it is a procedural complaint: actors like Make Sunsets are proceeding in much the same way as someone who announces on the first day of practice that they will be playing center in the soccer match before any decisions are made about how such matters are decided. This observation doesn't yet tell us *how* player positions should be assigned; likewise, the observation that start-ups are proceeding without governance structures doesn't tell us what governance structure should be implemented. While the objection thus impugns the actions of 'rogue geoengineers,' it is, in principle, compatible with claiming that the appropriate governance of solar geoengineering *allows* for a 'cooling credit' model at some point in the future.

None of this shows that the governance-first objection itself is unconvincing. Indeed, the procedural concerns mentioned above seem like a decisive objection to the current practices of Make Sunsets. My point is that the objection is a relatively narrow one. It is not itself a case against cooling credits. Rather it's a case against cooling credits *prior* to some procedure for determining how solar geoengineering is to be governed and putting in place that governance. We'll need a separate argument for the claim that the right governance structures would rule out the market-based approach over the long term.

Note that the same point applies to complaints that private entities entering the solar geoengineering space fail to satisfy norms of *procedural justice* by failing to inclusively engage with local communities prior to their activities.[13] This critique is a pressing one. But a call for greater engagement and deliberation about solar geoengineering does not amount to an argument against a particular way of governing the research or use of the technology—except, of course, for the procedural aspects of governance themselves. The procedural critique condemns *making* such a decision without the right sort of prior engagement.[14]

[13] For a discussion of different components of justice in the context of geoengineering, see Hourdequin (2018).
[14] If one holds the position that the outcome of just deliberation *fully determines* the substantively just policy, then this point would not stand. Further

Relationship with Abatement

A thought that has surely occurred to you concerns the climatic difference between solar geoengineering and abatement. Solar geoengineering, after all, does not return us to a world with fewer cumulative CO_2 emissions. Even for the same amount of global mean temperature reduction, solar geoengineering operates differently on the climatic system than mitigation. It will alter temperature and precipitation patterns differently than mitigation alone (Zarnetske et al. 2021; Jiang et al. 2019; Bala et al. 2008).

Importantly, the fact that solar geoengineering would result in a different distribution of risks than the same amount of avoided warming via mitigation does not yet amount to an objection to the use of cooling credits, as some have suggested.[15] Governments routinely adopt (presumably unproblematic) policies that change the distribution of risks and benefits, making some people better off at the expense of others. Presumably, it is often permissible for governments to enact policies that are not strict Pareto improvements.[16]

Indeed, strictly speaking, the current system of CDR accounting also faces this challenge. When removals occur years or decades after the emissions they are meant to offset, atmospheric CO_2 concentrations—and therefore climate risks—remain higher during the intervening period. Even if we are not in an epistemic situation to specify how the risk profile has shifted, some redistribution of risks and benefits clearly occurs. Consequently, the mere fact that solar geoengineering (relative to an equivalent amount of avoided warming through mitigation) reshapes the pattern of risks (or fails to deal with some risks, such as ocean acidification) cannot, by itself, explain why cooling credits are objectionable.

Nevertheless, there is something important about the observation that solar geoengineering and abatement are not *fungible* in the way imagined by proponents of cooling credits. Here's a starting point for an alternative explanation. Solar geoengineering and mitigation are *distinct obligations* owed to distinct populations.[17] One can't keep a promise owed to their mother by keeping a promise with their father, and governments can't make up for a failure to enact just policies for their own citizens by advancing justice elsewhere. More generally, governments can't make up for a failure to perform some morally required task X owed to group S by performing another morally required task Y owed to group P. [18] Solar geoengineering, you might argue, is a project that primarily benefits people in the relatively short term. The duty to

[15] I see this thought reflected in the arguments presented by Diamond et al. (2023). They write that "The distribution of risks and benefits will therefore differ between mitigation and a solar climate intervention even for the same amount of avoided global mean warming," (96) and on my reading suggest that this is a reason to be skeptical of the cooling credits model.

[16] Even if we (a) understood the side-effects of solar geoengineering well and (b) imposed a Pigouvian tax on the sale of such cooling credits, this would still amount to re-distribution of risk, since the goal of such a tax is to ensure that the transaction occurs only at the socially efficient level.

[17] I frame solar geoengineering as *obligatory* here. I don't agree with this characterization, but I do so to show that even *if* pursuing deployment of solar geoengineering is a moral duty or obligation, we *still* cannot satisfy obligations in one domain with obligations in another. So much the better for my argument if pursuing solar geoengineering is not an obligation.

[18] Things might look different if we turn from thinking about what *states* ought to do to the ethics of *individual* offsets or cooling credits. Some philosophers have engaged in a lively debate over whether it is impermissible to purchase a carbon offset to compensate for one's emissions in in doing so one will shift the distribution of risks and benefits. See (Barry and Cullity 2022; Berkey 2024)

decarbonize our energy systems is a longer-term project, owed primarily but not only to people who will live in the long-term future.[19]

Of course, more would need to be said to defend the philosophical foundation on which this picture—call it the 'separate responsibilities' picture—rests.[20] I'll say a bit more below, but I think this route is a promising way to proceed. Notice, though, that the above reflections *still* don't amount to an objection to the very idea of a 'cooling credit' market. Rather, the objection is to a particular way that cooling credits might be used*;* namely, in *place of* emissions reductions that would reduce radiative forcing by an equivalent amount for a given period.

To return to our analogy from earlier, there is no objection to taking care of your friend's child in *addition* to your own. And we can at least *imagine* a world with appropriately stringent restrictions on CO_2 emissions, where private companies will inject aerosols into the stratosphere for you for a fee. In such a world, I am far less concerned with the practice of buying and selling cooling credits, provided their deployment is procedurally just and governed by a central body like the one described above.[21] What makes the practice of cooling credits so objectionable (in addition to the procedural worries) is the *absence of wide-scale restrictions on CO_2 emissions.* One (or the main) *reason* that cooling credits are objectionable is not the mere fact that such a system distributes risks differently, but that such a system involves conflating two distinct responsibilities.

The 'separate responsibilities' picture may seem self-evident to those of us used to hearing the mantra that solar geoengineering is "no substitute for emissions reductions". Nevertheless, I think it is worth defending, for a few reasons. First, I think the idea that 'heat' is the ultimate driver of climate impacts and thus reducing radiative forcing should be the central goal of climate policy is likely to be politically alluring regardless of its scientific merit.

Second, the separate responsibilities view also runs against the idea of simple Integrated Assessment Modeling efforts, where the main objective is to suggest 'optimal' (welfare-maximizing) climate policy. On the normative picture embedded in these models, there is just *one* responsibility: to maximize global welfare (or, on a different set of models, to show the most cost-effective way of reaching a given climate target). According to models like these solar geoengineering and emissions reductions are not fundamentally two distinct obligations. Indeed, we see this result reflected in IAMs that have incorporated solar geoengineering. Heutel et al. (2018) find, for instance, that allowing solar geoengineering lowers the optimal level of emissions reductions, letting humanity emit roughly 600 Gt CO_2 more in total—about 15 years of today's emissions—before atmospheric carbon reaches its peak.[22] Thus, the 'separate responsibilities' claim entails rejecting the picture at the heart of these models. It also involves

---

[19] It's not essential that the duties are owed to different populations, simply that they are *distinct* obligations. I'll set aside the so-called 'non-identity problem' here. For explanation see Parfit (2010).

[20] Philosophers call duties owed *to particular people* (as opposed to, say, a duty to maximize welfare or increase equality), 'directed duties.'

[21] Are cooling credits entirely unobjectionable in a situation like this? Certainly, some potential objections remain, such as the concern among environmental ethicists that geoengineering reinforces a kind of environmental hubris. See Jamieson (1996) for this view.

[22] Heutel et al. (2018) find that introducing solar geoengineering into an optimizing model raises the peak atmospheric stock from ≈ 1,780 Gt C to ≈ 1,850 Gt C (a 70 Gt C ≈ 257 Gt CO_2 increase). Assuming 45 % of each tonne emitted stays aloft, that implies ~600 Gt CO_2 of extra cumulative emissions

rejecting a view on which solar geoengineering is fundamentally about *buying time*—in other words, that solar geoengineering *justifies* a slower energy transition. We can see, then, that reflecting on the permissibility of cooling credits leads us quickly to a deeper question about how to view the relationship between solar geoengineering and emissions reductions.

Indeed, I think the same point holds regarding carbon dioxide removal: the normative status of a market in carbon dioxide removal awaits an answer to the question of whether carbon dioxide removal and emissions reductions are to be conceived of as two distinct tasks, or whether they are merely interchangeable means of delivering *benefits,* broadly construed, to be differentiated by cost.

Conclusion

The idea for this paper began with the observation that, while the idea of markets in 'cooling credits' has been widely condemned, I suspect that there is disagreement regarding the exact nature of the condemnation that is worth spelling out. Moreover, it struck me as surprising how widespread the uproar was about 'cooling credits' when market-based approaches are supported by many in the context of carbon removal and other climate policy mechanisms. Thus, my question: What, if anything, is wrong about cooling credits?

I began by surveying three answers to this question. One answer is that there is no business case for cooling credits. Another answer is that cooling credits set back legitimate research or potential deployment of solar geoengineering. A third answer is that the current practice of cooling credits has failed to satisfy requirements of procedural justice. I find these answers unsatisfying, at least as an explanation for why the 'cooling credits' approach to solar geoengineering is problematic over the long term.

I then turned towards the idea that cooling credits are problematic because solar geoengineering has different impacts than emissions reductions alone. This insight is on to something, but we can't object to cooling credits merely by pointing out that it has a different risk profile than mitigation. Instead, I proposed that the correct explanation is that we should see solar geoengineering and abatement as distinct obligations owed to different sets of individuals. I did not provide a full argument for this picture. Instead, I briefly defended that such a defense is indeed needed. Perhaps it seems *obvious* that solar geoengineering and emissions reductions represent two different responsibilities, but such a view has strong implications. The 'separate responsibilities' picture, as I've called it, would push against the standard economic goal of maximizing welfare and the related view that solar geoengineering is about 'buying time.'

Another subtle message of this paper is that, in addition to articulating *procedural* concerns regarding solar geoengineering, we should think about substantive concerns as well. In other words, we need to consider not only *how* decisions about this technology should be made, but also to discuss and debate *what* decisions ought to be made. These deliberations can then be inputs into the appropriate procedure. In this vein, I've tried to issue a call for further articulation and debate regarding what, if anything, is wrong about the market-based approach to solar geoengineering.

Works Cited

Bala, G., P. B. Duffy, and K. E. Taylor. 2008. “Impact of Geoengineering Schemes on the Global Hydrological Cycle.” *Proceedings of the National Academy of Sciences* 105 (22): 7664–69. world. https://doi.org/10.1073/pnas.0711648105.

Barry, Christian, and Garrett Cullity. 2022. “Offsetting and Risk Imposition.” *Ethics* 132 (2): 352–81. https://doi.org/10.1086/716871.

Berkey, Brian. 2024. “When Is It Permissible to Impose and Offset Risks? A Response to Barry and Cullity.” *Ethics* 134 (4): 512–24. https://doi.org/10.1086/729709.

Biermann, Frank, Jeroen Oomen, Aarti Gupta, et al. 2022. “Solar Geoengineering: The Case for an International Non-use Agreement.” *WIREs Climate Change* 13 (3): e754. https://doi.org/10.1002/wcc.754.

Climeworks. 2024. *Climeworks: Pioneering the Race to Net Zero*. https://climeworks.com/uploads/documents/2024_climeworks_pioneering_the_race_to_zero.pdf.

Cowen, Tyler, ed. 2018. *Public Goods and Market Failures: A Critical Examination*. Routledge.

Diamond, Michael S., Kelly Wanser, and Olivier Boucher. 2023. “‘Cooling Credits’ Are Not a Viable Climate Solution.” *Climatic Change* 176 (7): 96. https://doi.org/10.1007/s10584-023-03561-w.

Gardiner, Stephen. 2014. “Why ‘Global Public Good’ Is a Treacherous Term, Especially for Geoengineering.” *Climatic Change* 123 (2): 101–6. https://doi.org/10.1007/s10584-014-1079-2.

Harris, Mark. 2024. “Make Sunsets Is a Controversial Solar Geoengineering Startup.” *IEEE Spectrum*. https://spectrum.ieee.org/solar-geoengineering-2669008650.

Heutel, Garth, Juan Moreno-Cruz, and Soheil Shayegh. 2018. “Solar Geoengineering, Uncertainty, and the Price of Carbon.” *Journal of Environmental Economics and Management* 87 (January): 24–41. https://doi.org/10.1016/j.jeem.2017.11.002.

Hourdequin, Marion. 2018. “Climate Change, Climate Engineering, and the ‘Global Poor’: What Does Justice Require?” *Ethics, Policy and Environment* 21 (3): 270–88. https://doi.org/10.1080/21550085.2018.1562525.

Jamieson, Dale. 1996. “Ethics and Intentional Climate Change.” *Climatic Change* 33 (3): 323–36. https://doi.org/10.1007/BF00142580.

Jiang, Jiu, Long Cao, Douglas G. MacMartin, et al. 2019. “Stratospheric Sulfate Aerosol Geoengineering Could Alter the High-Latitude Seasonal Cycle.” *Geophysical Research Letters* 46 (23): 14153–63. https://doi.org/10.1029/2019GL085758.

Mckinsey Sustainability. 2023. “Carbon Removals: How to Scale a New Gigaton Industry.”

Miller, Stephen Robert. 2024. *Inside Silicon Valley’s Grand Ambitions To Control Our Planet’s Thermostat*. August 8. https://www.noemamag.com/inside-silicon-valleys-grand-ambitions-to-control-our-planets-thermostat.

Morrow, David R. 2014. “Why Geoengineering Is a Public Good, Even If It Is Bad.” *Climatic Change* 123 (2): 95–100. https://doi.org/10.1007/s10584-013-0967-1.

Parfit, Derek. 2010. “Energy Policy and the Further Future: The Identity Problem.” In *Climate Ethics*, by Derek Parfit. Oxford University Press. https://doi.org/10.1093/oso/9780195399622.003.0015.

Ramos, Yvette, and Filipe Duarte Santos. 2025. “Are Climate Geoengineering Technologies Being Patented? An Overview.” *Climate* 13 (4): 77. https://doi.org/10.3390/cli13040077.

Surprise, Kevin, Duncan McLaren, Ina Möller, J.P. Sapinski, Doreen Stabinsky, and Jennie C. Stephens. 2025. “Profit-Seeking Solar Geoengineering Exemplifies Broader Risks of Market-Based Climate Governance.” *Earth System Governance* 23 (January): 100242. https://doi.org/10.1016/j.esg.2025.100242.

Trencher, Gregory, Sascha Nick, Jordan Carlson, and Matthew Johnson. 2024. “Demand for Low-Quality Offsets by Major Companies Undermines Climate Integrity of the Voluntary Carbon Market.” *Nature Communications* 15 (1): 6863. https://doi.org/10.1038/s41467-024-51151-w.

VanDeveer, Stacy D., Frank Biermann, Rakhyun E. Kim, Carol Bardi, and Aarti Gupta. 2024. “Three Pathways to Nonuse Agreement(s) on Solar Geoengineering.” *Ethics & International Affairs*, December 16, 1–12. https://doi.org/10.1017/S0892679424000285.

Zarnetske, Phoebe L., Jessica Gurevitch, Janet Franklin, et al. 2021. “Potential Ecological Impacts of Climate Intervention by Reflecting Sunlight to Cool Earth.” *Proceedings of the National Academy of Sciences* 118 (15): e1921854118. https://doi.org/10.1073/pnas.1921854118.