

Implications of the Paris Agreement for Carbon Dioxide Removal and Solar Geoengineering



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The Paris Agreement (“Agreement”)¹ has been widely lauded as a major step forward in multilateral efforts to address global climate change. Its bottom-up approach based on national pledges, its universal scope entailing substantive commitments by both developed *and* developing countries, its ambitious climate targets, and other aspects of the Agreement have generated extensive discussion, drawing praise from many and eliciting criticism from others (e.g., Bodansky, 2015; Gillis, 2015; Victor, 2015; Winkler, 2015).

We survey the implications of the revamped climate policy regime for carbon removal and solar geoengineering, hereafter referred to using the common acronyms carbon dioxide removal (CDR) and solar radiation management (SRM). While a few analyses have examined the post-Paris role of CDR (Lewis, 2015), there has been almost no analysis of the implications for SRM. We first review the Agreement before turning to an examination of its implications for CDR and SRM.

Recap

Negotiations leading up to Paris and the Agreement itself were premised on two fundamental departures from past UNFCCC practice. First, the bottom-up orientation of COP-21, based on so-called intended nationally determined contributions (INDCs) prepared and submitted by individual governments, broke with the established pattern of top-down targets and timetables epitomized by the Kyoto Protocol. Second, the expectation that all countries—developed and developing—would take substantive action introduced a new conception of “differentiated responsibility.”

1 The text of the Agreement and accompanying COP Decision may be found at: <http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf>.

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The centerpiece of the Agreement is its commitment (Article 2) to limit the global average temperature increase to “well below” 2 °C above preindustrial levels, and to undertake efforts to limit it to 1.5 °C. Whether or not individual negotiators intended these targets, in particular 1.5 °C, to be symbolic, aspirational goals rather than concrete, achievable policy objectives, their inclusion has set new benchmarks against which future action will be measured.

The Agreement’s most important institutional achievement is likely the creation of a five-year review cycle for mitigation targets as articulated in NDCs.² In the event that these reviews fail to spur countries to adequately strengthen their commitments over time as the Agreement requires (Article 3), new policy mechanisms will be necessary. Another important outcome of practical relevance is the decision to allow for two new market mechanisms to promote mitigation: the Sustainable Development Mechanism (SDM), a centrally governed instrument meant to succeed the Kyoto Protocol’s CDM, and less coordinated “internationally transferred mitigation outcomes” (ITMOs) to address internationally traded greenhouse gas units (both provided for in Article 6). A final outcome of note is an invitation to the Intergovernmental Panel on Climate Change (IPCC) (since accepted) to prepare a special report by 2018 on emission pathways compatible with 1.5 °C.

Given its agreed pledges, will the Agreement achieve its goals? One prominent analysis concludes that the planet would still warm by 2.7 °C even with full implementation of the pledges (Jeffrey et al., 2015). But this analysis, and most others, suppose that there is a fixed budget for cumulative carbon emissions that would allow the world to stay under some threshold, such as 1.5 °C or 2 °C. This assumption conceals one of the central physical realities of climate change: the amount of climate change for a given amount of carbon emissions—the climate sensitivity—is deeply uncertain. That uncertainty has persisted with little change for decades. Policymakers would do well to view it as irreducible uncertainty.

The fine print in all analyses of the Agreement’s ability to meet its objectives based on current pledges includes a statement about the probability of staying under the given temperature threshold. The study quoted above, for example, actually says that if all pledges are implemented the world has a 50 percent chance of staying under 2.7 °C and a 66 percent chance of staying under 3 °C. The accord itself makes no statement about probability, and thus in some basic sense it is impossible to judge analytically whether or not the targets can be met based on the pledges. CDR can reduce carbon concentrations with the resulting temperatures subject to the same climate sensitivity uncertainty, whereas SRM may alter temperatures more directly but does so by partially masking the climate response to accumulated greenhouse gases.

² Once a party formally accedes to the Agreement, its INDC is relabeled an NDC.

CDR

While the UNFCCC has recognized and promoted some forms of CDR since its inception, in particular afforestation and reforestation under the CDM, the Agreement marks a major upgrade in the role envisioned for CDR technologies in climate policy.

It seems unlikely that the <2 °C target can be met with emission reductions alone, as economic models indicate that the carbon price required to achieve this would be prohibitively high (Edmonds et al., 2013). The Agreement's temperature targets therefore carry huge implications for CDR and SRM. The Integrated Assessment Modeling (IAM) community has developed a set of analyses which do allow for a significant likelihood of meeting a <2 °C target, but all of these analyses assume wide-scale application of CDR technologies, typically involving bioenergy with carbon capture and storage (BECCS) and afforestation/reforestation.

Nevertheless, while most IAMs indicate a roughly two-thirds probability of meeting the <2 °C target if very strong mitigation and CDR efforts are pursued, it is doubtful that such measures would be sufficient to keep global mean temperature increase at 1.5 °C. Those few studies which suggest that mitigation and negative emissions alone could deliver a 1.5 °C world (e.g., Rogelj et al., 2015) rely on heroic assumptions about the speed, scale, and scope of "very deep decarbonization." Although technically possible, achieving such a rapid transformation would necessitate draconian social measures incompatible with market economies.

While the Paris framework does not contain a specific mandate for parties to start removing carbon from the atmosphere, it provides many of the tools necessary for pursuing this in practice. The scope of "mitigation" activities under the Agreement explicitly includes removal of carbon dioxide: Article 4 calls for achieving "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century." Furthermore, specific policy instruments under the Agreement appear applicable to CDR. The two provisions on market mechanisms mentioned in the previous section could evolve into crucial support instruments for the deployment of GHG removal technologies and practices.

Discussion of specific technologies at COP-21 and its side events was limited mainly to the forestry and agriculture sectors. But given their essential role in meeting the Paris targets, CDR methods, especially BECCS, have garnered increased awareness and scrutiny since the COP concluded (Anderson, 2015). Given the very limited industrial experience with CDR technologies, the selection of BECCS as the primary CDR technology used in IAMs, and the specific assumptions made about the technology, are questionable at best.

In sum, the Agreement has brought CDR technologies to the forefront of climate policy discussions. Although it does not call for CDR *per se*, core elements of the Agreement—including the highly ambitious temperature targets, the explicit mentioning of anthropogenic removals, and the commitment to achieve a “balance” between emissions and removals—are based on the assumption that CDR will be widely used to help reduce atmospheric concentrations of CO₂ over the coming century. Of course, the conclusion that meeting ambitious temperature targets requires CDR depends on the implicit assumption that SRM is not used.

Whether adoption of CDR technologies will be achieved in practice depends crucially on how the Agreement’s policy framework develops, including the evolution of NDCs, the effectiveness of “naming and shaming,” and the specification and operationalization of the SDM and the ITMO mechanism. Many barriers to success remain, most importantly an underlying incentive structure that encourages free-riding and collective inaction. While the introduction of CDR technologies may marginally improve some incentives for countries and other actors to mitigate, it does not fundamentally alter interests in a way that significantly increases the likelihood of reaching socially optimal outcomes. On its own, therefore, the elevation of CDR methods as a central component of international climate policy at COP-21 will likely prove insufficient to halt our current business as usual emissions trajectory, let alone limit global warming to <2 °C (or 1.5 °C).

SRM

While CDR featured in Paris in all but name, there was essentially no discussion of SRM in any of the negotiations, proceedings, or side events. Before turning to the policy and politics of SRM as part of the post-Paris climate regime, we briefly summarize current understanding of SRM.

First, there is no substantive disagreement that some forms of SRM, such as the injection of reflective aerosols in the stratosphere, would reduce global radiative forcing and surface temperatures. Second, this reduction in radiative forcing carries with it new risks and uncertainties, and there is no sense in which increasing the Earth’s reflectivity is the equivalent of reducing carbon dioxide concentrations. At best SRM is a supplement to emissions mitigation, not a substitute for it. Third, while analysis of SRM going back decades has consistently shown that it could reduce surface temperatures, there has been deep uncertainty about its ability to slow climate change on a regional level, and its effects on changes in other important variables such as precipitation, sea level rise, and extreme events have been unclear.

Over the last half-decade, however, analysis using state-of-the-art climate models has shown that under moderate amounts of SRM—such as the amount required to stop the increase in global precipitation forecast under a business-as-usual scenario—almost all regions of the world would

experience climates closer to preindustrial conditions with SRM compared to what they would experience without it (Kravitz et al., 2014). In other words, SRM may be efficacious in reducing the dimensions of climate change more broadly, not just global average surface temperature. Fourth, and finally, it appears that some forms of SRM could be deployed at very low cost (less than 0.1 percent of global GDP) using existing technologies (McClellan, Keith, and Apt, 2012).

Turning back to the Agreement with its specific temperature targets, and keeping in mind the deep uncertainty about climate sensitivity noted above, one can conclude that a target like $<2\text{ }^{\circ}\text{C}$ or $1.5\text{ }^{\circ}\text{C}$ cannot be met with high confidence without at least the ability to implement SRM if climate sensitivity proves to be high. Despite this apparent fact, SRM is not explicitly referenced anywhere in the Agreement or decision 1/CP.21. Given the growing visibility of SRM—IPCC head Hoesung Lee recently called for additional research on the subject (Goldenberg, 2016)—the absence of discussion of SRM at Paris cannot simply be attributed to ignorance on the part of delegates. Rather, the subject was deliberately avoided because at least some negotiators believed that it was a highly polarizing issue on which they would be very unlikely to get any substantive agreement.

Yet the fact that the Agreement contains explicit quantitative temperature goals instead of, say, an explicit carbon budget goal (due largely to continuing objections from oil-exporting states) actually facilitates the eventual inclusion of SRM in the post-Paris system. SRM would affect temperature via changes in radiative forcing rather than changes in carbon emissions, so SRM is directly applicable to achieving the central goals of the Agreement, whereas it is not directly relevant to meeting emissions targets like those embodied in the Kyoto Protocol.

How might SRM enter mainstream policy discussions under the Paris framework? One route might be the 2018 IPCC special report on $1.5\text{ }^{\circ}\text{C}$ mentioned above. Although its terms are expressly restricted to examining “global greenhouse gas emission pathways,” it is difficult to see how a realistic, policy-relevant report can be delivered whose terms are not expanded to include the possible use of SRM. Given the evident reluctance to add SRM to the climate policy agenda, however, any attempt to broaden the scope of the report to include SRM is likely to be strongly resisted by substantial segments of the international science policy community.

If SRM were to enter into the climate policy framework agreed to in Paris, where might it fit? It is tempting to assume that some modification of the market approaches outlined in Article 6 might provide an opportunity for integrating SRM. Yet these mechanisms are either defined explicitly in terms of mitigating GHG emissions (SDM) or appear to offer little interpretive room for inclusion of SRM (ITMOs). Even if mechanisms were adapted, for example by paying for delivery of a certain number of watts per square meter (i.e., radiative forcing), we would strongly oppose using markets to implement SRM. Unlike reducing emissions, which is a costly activity involving an enormous

number of independent actors guided only by central coordination on the sum total, SRM presents a case where cost matters much less than the legitimacy of the country or group of countries making decisions about how much to implement. In other words, with SRM, the importance of market efficiency pales in comparison to the fundamental political issue of who has the right to act.

We do not see potential for any other element of the Agreement to serve as an entry point for the integration of SRM into the current climate policy toolbox. Instead it appears that serious inclusion of SRM will require a deep revision of the Paris framework. But the fact that the Paris framework is based on ambitious temperature targets will likely lead to greater discussion and debate about SRM, which is a necessary precondition to its incorporation into any future climate regime.

In sum, the Agreement heralds a potentially significant new role for SRM in efforts to combat climate change, particularly in the context of its ambitious 1.5 °C target. While SRM was effectively treated as unmentionable in Paris for fear of derailing negotiations, it is doubtful that this can continue in a policy climate now defined by goals that may well require it. The IPCC special report on 1.5 °C may prove to be an especially fruitful vehicle for broaching a candid discussion about SRM as an essential part of any credible strategy for achieving the world's ambitious climate goals.

Conclusion

The Agreement and its attendant policy framework treat CDR and SRM very differently. On the one hand, the Agreement explicitly recognizes the central role of “anthropogenic removals by sinks” in achieving the objectives of international climate policy and includes policy instruments that could enable CDR. Discussion of SRM, by contrast, is completely absent from the policy discourse emanating from COP-21. This is paradoxical given the Agreement's ambitious temperature targets that all but necessitate taking SRM seriously.

Yet meeting the Agreement's temperature goals with any confidence implicitly requires a portfolio that includes both implementation of CDR and research to—at a minimum—develop the ability to implement SRM. While CDR's newfound prominence at the center of climate policy might seem to ease the challenge of managing carbon, the economics of CDR are, in fact, very similar to those of emissions mitigation: both entail high, local, short-term costs that discourage widespread deployment. These obstacles, however, do not apply to SRM, which models demonstrate would be capable of limiting global warming to 1.5 °C above preindustrial levels (if this were desired in the future), albeit with known and likely unknown side effects and serious governance challenges. As Weitzman (2015) has convincingly argued, SRM has the potential to change the free-rider problem of undersupplied emissions mitigation (and by extension CDR) into a free-driver problem of oversupplied SRM requiring international restraint and cooperation.

One possible mode of cooperation would involve linking the right to participate in decision-making about SRM to a commitment to significant emission reductions (Parson 2014). Whether or not the Paris framework is amenable to such linkage is unclear. The promotion of CDR methods alongside conventional mitigation approaches may enhance the scope for bargaining required to cement such linkages. This is just one of many possibilities afforded by the Agreement, whose minimalist architecture provides ample scope to begin to weave together emissions cuts, large-scale CDR, adaptation, addressing loss and damage, and potentially SRM as complementary elements of a broad portfolio approach to climate risk reduction. It would be deeply unfortunate if, instead, the Agreement's silence on institutional details permitted the world once again to avoid hard choices about climate, technology, and governance.

References

- Anderson, K. (2015). Talks in the City of Light generate more heat. *Nature*. www.nature.com/news/talks-in-the-city-of-light-generate-more-heat-1.19074.
- Bodansky, D. (2015, December). Reflections on the Paris Conference. *Opinio Juris*. <http://opiniojuris.org/2015/12/15/reflections-on-the-paris-conference>.
- Edmonds, J., P. Luckow, K. Calvin, M. Wise, J. Dooley, P. Kyle, S. Kim, P. Patel and L. Clarke. (2013). Can radiative forcing be limited to 2.6 Wm⁻² without negative emissions from bioenergy AND CO₂ capture and storage? *Climatic Change* 118(1):29-43. <http://dx.doi.org/10.1007/s10584-012-0678-z>.
- Gillis, J. (2015, December 12). Climate accord is a healing step, if not a cure. *New York Times*. www.nytimes.com/2015/12/13/science/earth/climate-accord-is-a-healing-step-if-not-a-cure.html.
- Goldenberg, S. (2016, May 11). UN climate science chief: It's not too late to avoid dangerous temperature rise. *The Guardian*. www.theguardian.com/environment/2016/may/11/un-climate-change-hoesung-lee-global-warming-interview.
- Jeffrey, L., C. Fyson, R. Alexander, J. Gutschow, M. Rocha, J. Cantzler, M. Schaeffer, B. Hare, M. Hagemann, N. Höhne, P. van Breevoort, and K. Blok. (2015, December 8). 2.7°C is not Enough – we can get lower. *Climate Action Tracker Update*. http://climateactiontracker.org/assets/publications/briefing_papers/CAT_Temp_Update_COP21.pdf.
- Kravitz, B., D. G. MacMartin, A. Robock, P.J. Rasch, K.L. Ricke, J.N.S. Cole, C.L. Curry, P.J. Irvine, D. Ji, D. W. Keith, J.E. Kristjánsson, J.C. Moore, H. Muri, B. Singh, S. Tilmes, S. Watanabe, S. Yang, and J.-H. Yoon. (2014). A multi-model assessment of regional climate disparities caused by solar geoengineering. *Environmental Research Letters*, 9. <http://iopscience.iop.org/article/10.1088/1748-9326/9/7/074013/pdf>; <http://dx.doi.org/10.1088/1748-9326/9/7/074013>.
- Lewis, S. (2015, December). The dirty secret of the Paris climate deal. *Foreign Policy*. <http://foreignpolicy.com/2015/12/17/the-dirty-secret-of-the-paris-climate-deal-carbon-capture-negative-emissions-global-warming>.
- J. McClellan, D. W. Keith and J. Apt. (2012). Cost analysis of stratospheric albedo modification delivery systems. *Environmental Research Letters*, 7: 034019 (8pp). <http://dx.doi.org/10.1088/1748-9326/7/3/034019>.
- Parson, E.A. (2014). Climate engineering in global climate governance: Implications for participation and linkage. *Transnational Environmental Law*, 3(1):89-110. <http://dx.doi.org/10.1017/S2047102513000496>.

- Rogelj, J., G. Luderer, R.C. Pietzcker, E. Kriegler, M. Schaeffer, V. Krey, and K. Riahi. (2015). Energy system transformations for limiting end-of-century warming to below 1.5°C. *Nature Climate Change*, 5:519-527. www.nature.com/nclimate/journal/v5/n6/full/nclimate2572.html.
- Victor, D. (2015, December 15). Why Paris worked: A different approach to climate diplomacy. *Yale Environment 360*. http://e360.yale.edu/feature/why_paris_worked_a_different_approach_to_climate_diplomacy/2940.
- Weitzman, M.L. (2015). A Voting architecture for the governance of free-driver externalities, with application to geoengineering. *The Scandinavian Journal of Economics*, 117(4):1049-1068. <http://dx.doi.org/10.1111/sjoe.12120>.
- Winkler, H. (2015, December 15). Paris Agreement: after climbing a great hill, many more to climb. *The Energy Research Centre's Blog*. www.ercblogs.co.za/2015/paris-agreement-after-climbing-a-great-hill-many-more-to-climb.

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