Climate Engineering Under the Paris Agreement

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Summary

Recent assessments of the international community's ability to hold the increase of global average temperature to well below 2°C, while pursuing efforts to limit that increase to 1.5°C, indicate that this goal is unlikely to be achieved without large-scale implementation of climate engineering (CE) technologies. In light of the prominent, albeit contested, role that CE is likely to play in international climate policy, this Article analyzes the specific provisions of the Paris Agreement with a view to assessing the extent to which the Agreement can provide an institutional framework to effectively govern CE internationally, and how it may shape the development and implementation of CE options. In particular, the Article examines a number of critical interpretive questions that will need to be addressed as states begin to develop CE technologies at large scales, including the need to provide guidance respecting the acceptability of exceeding the Paris targets before drawing down atmospheric CO_2 levels, the challenges for equity, human rights, and sustainability objectives that CE poses, and the need to incorporate CE technologies into accounting and incentive structures.

The Paris Agreement (PA) supplies a new architecture for international cooperation on global climate change that relies on bottom-up, national mitigation and adaptation plans.[1] At the center of the Agreement is the objective of limiting global average temperatures to "well-below 2°C" and "to pursue efforts to limit the temperature increase to 1.5°C"—a goal that appears increasingly unlikely to be achieved by relying on emission reductions alone.[2] The insufficiency of traditional approaches has led to calls to investigate and develop a broader portfolio of approaches that could contribute to the meeting of the PA goals. Chief among these potential new approaches are two distinct constellations of technologies, carbon dioxide removal (CDR) and solar climate engineering (SCE), that have fallen under the broader rubric of climate engineering (CE).

In light of the increased salience of CE in ongoing debates over climate change measures, this Article analyzes the individual provisions of the PA to assess how the central elements of the Agreement may influence future discussions associated with CE options. Our intention is not to present an argument in favor of or against the incorporation of CE regulation within the United Nations Framework Convention on Climate Change (UNFCCC)[3]—although, to some degree, integrating aspects of CE governance within the climate regime is inevitable. Rather, the Article seeks to provide an understanding of the intersection of the key legal and governance debates in relation to CE with the central commitments and institutions under the PA. By doing so, it seeks to draw attention to areas of potential future legal and policy debate, as well as possible avenues for improved cooperation and coherence.

1. Paris Agreement to the United Nations Framework Convention on Climate Change, *adopted* Dec. 12, 2015, T.I.A.S. No. 16-1104, U.N.T.C. ch. XXVII(7.d) [hereinafter PA]. For a detailed discussion of the PA, see The Paris Agreement on Climate Change: Analysis and Commentary (Daniel Klein et al. eds., 2017). *See also* Daniel Bodansky, *The Paris Climate Change Agreement: A New Hope?*, 110 Am. J. Int'l L. 288 (2016).
2. The emissions reduction pledges made by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to date put the globe on track for temperature increases of between 2.6-3.7°C by 2100. *See* Joeri Rogelj et al., *Paris Agreement Climate Proposals Need a Boost to Keep Warming Well Below 2°C*, 534 Nature 631, 634 (2016). Of the 204 scenarios in the Intergovernmental Panel on Climate Change's (IPCC's) *Fifth Assessment Report*, which project temperature increases below 2°C by 2100, 184 contemplate large-scale deployment of one form of carbon dioxide removal climate engineering (CE): bioenergy with carbon capture and storage (BECCS); IPCC, Climate Change 2014: Synthesis Report, Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 20-26 (Core Writing Team et al. eds., IPCC 2014) [hereinafter Fifth Assessment Report], *available at* https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf; Olivier Boucher et al., *Opinion: In the Wake of Paris Agreement, Scientists Must Embrace New Directions for Climate Change Research*, 113 Proc. Nat'l Acad. Sci. 7287, 7288 (July 5, 2016).
3. United Nations Framework Convention on Climate Change, *adopted* May 9, 1992, S. Treaty Doc. No. 102-38, 1771 U.N.T.S. 107 [hereinafter UNFCCC].

Two key presumptions underlie the Article. The first is that CE technologies and the debates that surround them will move from the periphery of climate discussions to the center. As a normative matter, this presumption is contested, with critics questioning the desirability and feasibility of both CDR and SCE. However, as elaborated below, as a descriptive matter, CE, particularly CDR, is rapidly becoming a more prominent feature of the international climate governance landscape.

Take, for example, the recent Intergovernmental Panel on Climate Change's (IPCC's) special report on the related impacts and pathways to achieve the 1.5°C goal,[4] which notes that all pathways that involve no or limited exceedance (overshoot) of the 1.5°C target require CDR. In scenarios that do not involve (unprecedented) rapid and wide-scale system transitions, the amount of CDR is significant and involves large-scale land use transitions. Given the importance of CDR to achieving the 1.5°C goal, the special report carefully examines the feasibility and implications of a reliance on CDR.[5]

Moreover, the special report also includes a lengthy consideration of SCE despite the fact that SCE remains a largely hypothetical technology.[6] The increased emphasis on CE in this report is indicative, in our view, of the centrality of CE in the post-PA era. In effect, the temperature goals that anchor the PA drive the demand for novel solutions to address climate change, which are increasingly being identified as CDR, and, to a lesser extent, SCE.

The second presumption is that the PA will remain, for the foreseeable future, the key institutional structure for international climate cooperation, and will thus be central to future discussion on CE. At present, the PA appears quite robust, with a faster-than-anticipated coming into force and adoption of implementation rules (referred to collectively as the Paris Rulebook) in most areas within the anticipated time frame.[7] There are no alternative fora for climate policy formation at the global level, and the Agreement itself addresses a broad cross section of issues. This is not to suggest that the PA will be the exclusive focus of international climate policymaking, but it is central to identifying the fundamental goals, principles, and procedures for international cooperation.

Putting these two presumptions together, a crucial line of inquiry will be assessing the extent to which the PA can provide an institutional framework that can effectively govern CE at the international level, or at least determine which aspects of CE are likely to be addressed through the PA institutions, and how the PA may shape the development and implementation of CE options. The centrality of the PA was further underlined by the failure of the international community to agree on a very modest proposed role for the United Nations Environment Programme (UNEP) in March 2019, which requested the executive director of UNEP to prepare an assessment of CE technologies and engage other treaty secretariats in such an assessment. The proposal, put forward by the Swiss government and supported by a dozen other countries, was withdrawn when it was clear it would not receive sufficient support.[8] The United Nations Environment Assembly (UNEA) experience indicates that at present there is little appetite for new international initiatives on CE, placing greater emphasis on existing institutions like the PA that will need to grapple with aspects of CE as a matter of their mandate.

Because the PA does not specifically refer to either CDR or SCE, interpretive questions arise about the extent to which CDR and SCE fall within the meaning of the text and intent of the PA. In order to address these questions, the Article begins with a brief description of CDR and SCE and their respective roles in a broader portfolio of approaches to addressing climate change.[9] We then consider the specific provisions of the PA, including the Preamble. Where relevant, we also look to the Paris Rulebook, as these rules elaborate on the intent and approaches that the Parties intend to pursue. Given the significant differences between CDR and SCE, we differentiate between the two throughout our analysis. Finally, in the concluding section, we consider the broader question of the implications of the governance approach taken in the PA, which imposes few substantive obligations on States but seeks to pursue collective goals through reflexive procedural mechanisms, and its suitability in addressing the governance issues associated with CDR and SCE.

I. CE Technologies, Roles, and Risks

CE is an umbrella term for a constellation of proposed technologies that are directed toward counteracting the climatic impacts of a buildup of greenhouse gases (GHGs) in the atmosphere. CDR technologies are designed to remove carbon dioxide (CO_2) directly from the atmosphere and store it geologically or biologically in either terrestrial or

4. IPCC, Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways 23-24 (Valérie Masson-Delmotte et al. eds., 2018) [hereinafter 1.5°C Report].
5. *Id*. at 118-24, 342-47.
6. *Id*. at 347-52.
7. *Matters Relating to the Implementation of the Paris Agreement*, Decs. 1/CP.24 and 3/CMA.1, UNFCC, U.N. Doc. FCCC/PA/CMA/2018/L.4 (2018) [hereinafter Paris Rulebook].
8. For a discussion of the proposal, see *Perspectives on the UNEA Resolution*, Harv. Solar Geoengineering Res. Program Blog, Mar. 29, 2019, https://geoengineering.environment.harvard.edu/blog/perspectives-unea-resolution.
9. Excellent overviews of the scientific and policy debates can be found in the following reports: National Academies of Sciences (NAS), Negative Emissions Technologies and Reliable Sequestration: A Research Agenda (2018) [hereinafter NAS Research Agenda]; John Shepherd, The Royal Society, Geoengineering the Climate: Science, Governance, and Uncertainty (2009); National Research Council (NRC), Climate Intervention: Reflecting Sunlight to Cool Earth (2015) [hereinafter NRC SCE Report]; NRC, Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration (2015) [hereinafter NRC CDR Report]; Stefan Schäfer et al., The European Transdisciplinary Assessment of Climate Engineering (EuTRACE): Removing Greenhouse Gases From the Atmosphere and Reflecting Sunlight Away From Earth (2015), https://www.iass-potsdam.de/sites/default/files/2018-06/EuTRACE_report_digital_second_edition.pdf.

ocean environments.[10] Actively considered CDR technologies include biomass energy with carbon capture and storage (BECCS), ocean iron fertilization, accelerated terrestrial or ocean mineral weathering, and direct air capture, as well as land management to create or enhance natural sinks.[11]

Most SCE methods focus on reducing the amount of solar radiation absorbed by the earth (currently estimated to be 235 watts per square meter)[12] by an amount sufficient to offset the increased trapping of infrared radiation by rising levels of GHGs.[13] SCE approaches take advantage of the albedo effect by artificially increasing the opportunities to reflect sunlight away from the earth's atmosphere, and include injecting highly reflective aerosols into the stratosphere, seeking to brighten the reflectivity of clouds by seeding them with seawater droplets, and the genetic modification of crops to increase their reflectivity.[14]

CE as part of a portfolio of responses to address climate change has been the subject of serious scientific and policy consideration for the past decade, but remains technologically underdeveloped and controversial. Substantial scientific research programs to reduce uncertainties about CE technologies have been recommended by science bodies, but have not materialized at the scale necessary to test the potential benefits and risks of such approaches.[15]

While CDR and SCE are often lumped together, each category of technologies raises quite different challenges and concerns, since they perform quite different roles within the climate regime.[16] CDR approaches supplement existing mitigation strategies by reducing the stock of CO_2 in the atmosphere, but unlike emission mitigation measures, decouple reductions from emissions both temporally and spatially, allowing removals to occur later in time and not necessarily in direct connection with specific emission activities.[17] The ability to decouple reductions from emissions is an important distinguishing factor from traditional mitigation. CDR technologies are also often referred to as negative emissions technologies because they can facilitate the withdrawal of CO_2 from the atmosphere such that the atmospheric concentrations are reduced below the level that they otherwise would have been without deployment.[18] This again raises important new issues, as CDR provides a means for safe GHG levels to be exceeded on the basis that CO_2 levels can be reduced at some point in the future.

By contrast, SCE is more of an adaptive strategy that reduces the rate of temperature increases, with potential to lower the severity of impacts or to lengthen the time it would take to reach those impacts, providing more time to reduce emissions through decarbonization and to take adaptive measures.[19] Whereas CDR operates on the cause of climate change (atmospheric CO_2 levels), SCE operates more directly on alleviating the effects of climate change. Because SCE generally operates on a planetary scale, its effects are diffusely felt, and it thus is unlike traditional adaptation measures, which tend to address localized effects such as flooding or droughts. This is not to suggest that the distribution of effects from SCE is evenly distributed—it is not.

Some CDR technologies when implemented at scale are projected to have potentially severe land use, water, and biodiversity consequences, as well as uncertain ecosystem impacts.[20] The land use impacts have implications for agriculture and food security, which carry with them human rights concerns, and trade offs against other sustainability goals. SCE technologies involve greater scientific uncertainty and also involve significant risks. Changes to global average temperatures would not be uniform at local levels and could have consequential impacts on precipitation patterns, potentially affecting food production in some regions of the world.[21] The impacts of more diffuse sunlight could likewise impact crop yields.[22]

Because SCE affects temperature, rather than GHG levels, it conceals warming associated with increasing GHG stocks in the atmosphere, requiring a long-term implementation commitment (> 100-150 years) to allow GHG stocks to decrease over time. Moreover, SCE approaches would not address other environmental concerns associated with CO_2 emissions, such as ocean acidification. Unlike CDR, which is projected to be expensive and involve significant lags between implementation and desired impacts on the global climate, SCE options, especially stratospheric aerosol injection, could be relatively inexpensive to deploy, and are designed to have immediate impacts on global temperatures.[23]

10. For a recent overview of various CDR technologies and their limitations, see European Academies' Science Advisory Council (EASAC), Negative Emissions Technologies: What Role in Meeting Paris Agreement Targets? (2018).
11. NAS Research Agenda, *supra* note 9, at 31-246.
12. Jeffrey T. Kiehl & Kevin E. Trenberth, *Earth's Annual Global Mean Energy Budget*, 78(2) Bull. Am. Meteorological Soc'y 197, 198 (1997).
13. Michael C. MacCracken, Beyond Mitigation: Potential Options for Counter-Balancing the Climatic and Environmental Consequences of the Rising Concentrations of Greenhouse Gases 15 (World Bank Policy Research Working Paper No. 4938, 2009).
14. For a more detailed discussion of SCE options, see William C.G. Burns, *Geoengineering the Climate: An Overview of Solar Radiation Management Options*, 46 Tulsa L. Rev. 283 (2012).
15. Shepherd, *supra* note 9, recommendation 1.3; NRC SCE Report, *supra* note 9, recommendation 4; NRC CDR Report, *supra* note 9, recommendation 2. The British Natural Environment Research Council initiated, in 2017, an £8.6 million research program on GHG removal technologies.
16. Ken Caldeira et al., *The Science of Geoengineering*, 41 Ann. Rev. Earth Planetary Sci. 231 (2013).
17. Guy Lomax et al., *Investing in Negative Emissions*, 5 Nature Climate Change 498 (2015).
18. Duncan McClaren, *A Comparative Global Assessment of Potential Negative Emissions Technologies*, 90 Process Safety & Envtl. Protection 489, 489 (2012).
19. David Keith & Douglas G. MacMartin, *A Temporary, Moderate, and Responsive Scenario for Solar Geoengineering*, 5 Nature Climate Change 201 (2015).
20. *See infra*, Section II.D. (Article 3).
21. Phillip Williamson & Ralph Bodle, Update on Climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework (Secretariat of the Convention on Biological Diversity Technical Series No. 84, 2016).
22. Jonathan Proctor et al., *Estimating Global Agricultural Effects of Geoengineering Using Volcanic Eruptions*, 560 Nature 480 (2018).
23. *See* Edward A. Parson & Lia N. Ernst, *International Governance of Climate Engineering*, 14 Theoretical Inquiries L. 307 (2013) (referring to SCE technologies as "high leverage").

Virtually every responsible commentator on CE is emphatic that CE technologies are not to be understood as an alternative to the mitigation of GHG emissions, but rather must be implemented as part of a portfolio of responses that would provide greater efficiency and flexibility, as well as potentially avoiding some of the more severe impacts associated with large average temperature increases.[24] Nevertheless, there remain significant concerns that the prospect of implementing CE in the future will reduce the incentive for States to implement mitigation and adaptation measures.[25]

The maturity of technological development is specific to each type of CE technology. Some approaches, such as those relating to improved land management and forestry, are addressed as part of existing mitigation strategies, and are well understood, although uncertainties remain about the scale effects.[26] Others, particularly SCE technologies, but also many CDR technologies, require further experimentation and development. Some of the uncertainty can be reduced through modelling and laboratory experiments, but field experiments are also required,[27] which have proven to be controversial.[28]

In addition to the extensive discussion of CDR technologies and acknowledgement of the potential, albeit uncertain, role of SCE in the IPCC's special report on 1.5°C, the potentially significant role of CE was acknowledged by the IPCC *Fifth Assessment Report*, where the *Climate Change 2014: Synthesis Report* contained a brief discussion of the role of CDR technologies (BECCS and afforestation) in many of the mitigation scenarios presented in the report, and the potential future role and limitations of CDR. The synthesis report also acknowledged the potential of SCE to offset global temperature rise and some of its effects, while recognizing the substantial levels of uncertainty and governance challenges associated with deployment.[29] The 2017 UNEP *Emissions Gap Report*, which assesses the extent to which current mitigation pledges are on track to meet the Paris goals of limiting warming to 2°C or 1.5°C, devoted an entire chapter to CO_2 removal.[30]

At present, the rules regulating marine geoengineering under the London Protocol, should they come into force, would be the only legally binding CE-specific rules adopted by international bodies.[31] Existing customary and treaty law may regulate elements of CE experimentation and deployment,[32] but the development of future rules is likely required.[33]

It is important not to essentialize the governance requirements for CE, which will be contingent to some degree on the individual technologies being proposed.[34] Governance will need to be both facilitative, ensuring that there is adequate support for research and development and that access to technologies is made available to States, as well as regulatory, and in some cases constraining. There is greater scope for national control over CDR activities, many of which will not entail physical externalities to other States; the major exception being ocean-based activities, which necessarily require communal governance.

This is not to suggest that aspects of terrestrial CDR technologies should not be subject to international oversight. For example, there will be a need for common accounting methods to quantify removals. In addition, many of the sustainability, ecosystem, and human rights implications associated with large-scale CDR will give rise to international governance demands. However, State sovereignty over natural resources and activities within their territory provides a more limited basis for constraining international regulation. SCE, on the other hand, is a global issue at deployment and large-scale experimental scales, necessitating global oversight.

Assessments of technologies will need to account for and minimize adverse effects, which will cut across environmental, economic, and social considerations. Attention to the legitimacy of research and assessment processes will militate strongly in favor of transparent and participatory

24. For example, reports, *supra* note 9, stress the criticality of focusing climate responses most heavily on mitigating emissions through reductions and adaptation.
25. The so-called moral hazard concern is discussed in Christopher J. Preston, *Ethics and Geoengineering: Reviewing the Moral Issues Raised by Solar Radiation Management and Carbon Dioxide Removal*, 4(1) Wiley Interdisc. Revs.: Climate Change 23 (2013). *See also* Albert C. Lin, *Does Geoengineering Present a Moral Hazard?*, 40(3) Ecology L.Q. 673 (2013). For an empirical assessment of the moral hazard argument, see Dan Kahan et al., *Geoengineering and Climate Change Polarization: Testing a Two-Channel Model of Science Communication*, 658(1) Annals Am. Acad. Pol. & Soc. Sci. 192 (2015).
26. The Royal Society & Royal Academy of Engineering, Greenhouse Gas Removal 26-28 (2018); Bronson W. Griscom et al., *Natural Climate Solutions*, 114 PNAS 11645 (2017); Pete Smith, *Soil Carbon Sequestration and Biochar as Negative Emission Technologies*, 22 Global Change Biology 1315 (2016).
27. *See* David Keith et al., *Field Experiments on Solar Geoengineering: Report of a Workshop Exploring a Representative Research Portfolio*, 372 Phil. Transactions Royal Soc'y Series A 2031 (2014); Robert Wood & Thomas P. Ackerman, *Defining Success and Limits of Field Experiments to Test Geoengineering by Marine Cloud Brightening*, 121(3) Climatic Change 459 (2013).
28. Editorial, *A Charter for Geoengineering*, 485 Nature 415 (2012) (describing controversy around the Stratospheric Particle Injection for Climate Engineering project). *See also* Neil Craik et al., *Regulating Geoengineering Research Through Domestic Environmental Protection Frameworks: Reflections on the Recent Canadian Ocean Fertilization Case*, 7(2) Carbon & Climate L. Rev. 117 (2013) (discussing controversy over privately funded ocean fertilization experiment).
29. Fifth Assessment Report, *supra* note 2, at 89.
30. UNEP, The Emissions Gap Report 2017 (2017) [hereinafter Emissions Gap Report].
31. *Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities*, IMO Res. LP.4(8) (Oct. 18, 2013).
32. Joshua B. Horton et al., *Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities*, 22 N.Y.U. Envtl. L.J. 225 (2015); Albert C. Lin, *Geoengineering Governance*, 8(3) Issues Legal Scholarship 9 (2009).
33. Albert C. Lin, *The Missing Pieces of Geoengineering Research Governance*, 100 Minn. L. Rev. 2522 (2016); Ralph Bodle & Sebastian Oberthür, Options and Proposals for the International Governance of Geoengineering (2014); Anna-Maria Hubert & David Reichwein, An Exploration of a Code of Conduct for Responsible Scientific Research Involving Geoengineering: Introduction, Draft Articles, and Commentaries (Institute for Advanced Sustainability Studies Working Paper, 2015).
34. *See* David Victor, *On the Regulation of Geoengineering*, 24(2) Oxford Rev. Econ. Pol'y 322 (2008); Parson & Ernst, *supra* note 23; Simon Nicholson et al., *Solar Radiation Management: A Proposal for Immediate Polycentric Governance*, 18(3) Climate Pol'y 322 (2018).

processes.[35] In the event of implementation, there will be a demand for technical regulation, governing matters such as accurate accounting of removals, and ensuring the permanence of sequestered carbon.

II. The Paris Agreement and Climate Engineering

A. *Legal Form*

The PA, which came into force in November 2016, is a legally binding treaty.[36] However, the provisions of the Agreement itself have varying normative status owing to the operative wording within each provision, requiring careful attention be paid to the specific provisions under consideration.[37] The PA is not identified as a protocol under Article 17 of the UNFCCC, but the PA conforms to the basic requirements of Article 17 in that only Parties to the UNFCCC may be Parties to the PA.[38] While the precise relationship between the UNFCCC and the PA is not specified, both agreements share common institutions, and the Preamble makes it clear that the PA is intended to meet the objectives and principles of the UNFCCC.[39] The latter point is of particular significance insofar as incorporation of CE into the broader UNFCCC framework requires that international cooperation on CE be subjected to the underlying principles of equity and "common but differentiated responsibilities and respective capacities."[40]

The PA adopts a very different approach from the Kyoto Protocol,[41] where the quantified emission reductions commitments are tied to a specific time frame, the first of which has expired and the second of which has not entered in force, though Parties are permitted to voluntarily comply in the interim.[42] The approach under the Kyoto Protocol was top-down insofar as the Parties determined reduction commitments collectively, and once these were committed, they became enforceable legal commitments, subject to the Kyoto Protocol's compliance procedures. In contrast, the core obligations under the PA do not expire, but commit States to prepare and communicate nationally determined contributions (NDCs) directed toward achieving the PA's objectives. The architecture is explicitly progressive (Articles 2, 4(3)), and is oriented toward transparency of efforts (Article 13) and periodic collective assessments of progress. This latter process is implemented through a mechanism referred to as global stocktaking, which requires, inter alia, the Parties to measure actual emission reduction efforts against the purpose and long-term goals expressed in the PA (Article 14).

The structure of the PA is unique among international environmental treaties in the degree to which the key substantive elements are determined at the discretion of each State and, once set, remain political not legal commitments. The realization of the PA's goals rely chiefly on procedural mechanisms that are intended to encourage reflection on the adequacy of the collective efforts and ambitions in light of the PA's principles and goals. Where those efforts fall short, the structure of the PA forces a reckoning that may broaden the discussion of the types of responses necessary. Insofar as CE technologies fall within the scope of responses contemplated by the PA, this reckoning could lead to a more explicit discussion of the role of CE technologies in meeting the PA's goals.

Under the Paris architecture, a central issue moving forward will be the extent to which CE technologies, as part of a broader portfolio of responses to climate change, become subject to oversight through the PA and its associated mechanisms. The form of oversight will be affected by the bottom-up and reflexive quality of governance under the PA. More substantive forms of regulation, such as imposing moratoriums on the deployment of identified technologies or direct international oversight of field experiments,[43] would appear to fall outside of the structure of the PA. This may have particular salience for SCE governance, which would require clear substantive forms of global control at stages beyond small-scale experiments.

In order to operationalize the PA, further requirements and procedures were developed by the Parties. This process, which sought to develop "modalities, procedures and guidelines" in relation to specific elements of the PA, was implemented through decisions of the Conference of the Parties (COP) serving as the meeting of the Parties to the PA (CMA) at its meeting in 2018.[44] The resulting implementing decisions, known collectively as the Paris Rulebook, provide further direction on all major commitments within the PA, with the exception of climate finance. Insofar as the implementing rules elaborate on the requirements of the PA and determine the practices of the Parties in relation to the PA, the Paris Rulebook may shed further light on the degree to which CE is integrated into the Paris framework.

35. Neil Craik & Nigel Moore, Disclosure-Based Governance for Climate Engineering Research (Centre for International Governance Innovation Paper No. 50, 2014).
36. Daniel Bodansky, *The Legal Character of the Paris Agreement*, 25(2) RECIEL 142 (2016).
37. Lavanya Rajamani & Jacob Werksman, *The Legal Character and Operational Relevance of the Paris Agreement's Temperature Goal*, 376 Phil. Transactions Royal Soc'y A 2119, 2122 (2018); Bodansky, *supra* note 36, at 143.
38. PA, *supra* note 1, art. 20(1).
39. *Id*. pmbl. para. 3.
40. UNFCCC, *supra* note 3, art. 3(1).
41. Kyoto Protocol to the UNFCCC, *adopted* Dec. 11, 1997, 2303 U.N.T.S. 162 [hereinafter Kyoto Protocol].
42. Doha Amendment to the Kyoto Protocol, *adopted* Dec. 8, 2012, C.N.718.2012.TREATIES-XXVII.7.c.
43. For example, the Parties to the Convention on Biological Diversity (CBD) sought to impose a moratorium on CE activities through a (nonbinding) decision of the CBD Conference of Parties (COP), *Biodiversity and Climate Change*, Dec. X/33, UNEP, U.N. Doc. UNEP/CBD/COP/DEC/X/33 (2010) [hereinafter CBD COP Decision].
44. Paris Rulebook, *supra* note 7; citations are to page numbers found in compilation document entitled "Proposal by the President," *available at* https://unfccc.int/sites/default/files/resource/Informal%20Compilation_proposal%20by%20the%20President_rev.pdf.

B. Preamble

Under international law, preambular language in a treaty is generally not legally binding.[45] However, such provisions serve the important role of helping to interpret the intention of the Parties to an agreement.[46] In light of the reflexive legal form of the PA, the Preamble should have a particularly important rhetorical role to play in ongoing discussions amongst the Parties on the evolution of national commitments and approaches to address climate change, including the acceptability of CE technologies and their integration as part of a portfolio of climate responses.

The Preamble continues to frame global climate cooperation in light of the principles of equity and common but differentiated responsibilities and respective capabilities, which is also reflected in the operative provisions of the PA.[47] As elaborated on below,[48] while the PA sidestepped the issue of burden-sharing through its bottom-up system of NDC, the equitable distribution of burdens and benefits still animates the broader climate regime and will remain a feature of climate discourse. Both CDR and SCE have important distributive consequences and the development and implementation of CE technologies will have to account for equitable considerations.

The Preamble also emphasizes the inseparability of climate change actions and responses to sustainable development. The breadth of the wording in relation to sustainable development is wide, referring to "climate change actions, responses and impacts," which indicates a concern with the full portfolio of climate responses. While the PA does not explicitly reference the United Nations Sustainable Development Goals, their adoption is welcomed in the decision giving effect to the PA.[49] Moreover, the linkage is manifested in the Preamble, which identifies a number of issues that form the basis of the Sustainable Development Goals, including poverty eradication, food security, oceans, biodiversity, and education. Several substantive articles of the Agreement also emphasize the need to ensure that the PA is implemented in a manner that is consistent with sustainable development obligations.[50]

The PA's Preamble also notably provides that the "Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights." Thus, the Parties have signalled that measures to address climate change, which could include CE, should take into consideration potential threats such responses might pose to vulnerable individuals and groups in the pursuit of aggregate social benefits.[51]

The use of the term "respective obligations on human rights" evinces the intent of the Parties to limit their adherence to existing human rights obligations, rather than creating new ones.[52] However, this clause would include consideration by the Parties as to whether CE interventions comply with existing human rights protections under both customary international law and treaties.[53] Unlike the other principles discussed above, human rights considerations are not found in any of the operative provisions of the PA, but matters that form the basis of substantive human rights, such as food production, poverty alleviation, protection of the rights of indigenous peoples, and development, are contained in its body.[54] Moreover, the PA implicitly supports several procedural human rights including the right to public participation and public access to information.[55]

Deployment of many climate geoengineering options, on both the CDR and SCE sides of the equation, could pose threats to human rights, especially if deployed at large scale.[56] For example, delivery of a relatively modest three gigatons of CO_2 (GT CO_2) equivalent negative emissions annually would require a land area of approximately 380-700 million hectares in 2100, translating into 7%-25% of agriculture land and 25%-46% of arable and permanent crop area.[57] This level of emissions removal would be equivalent to a startling 21% of total current human appropriated net primary productivity.[58] While it might be possible to reduce these impacts by more of an emphasis on the use of agricultural residue and waste feedstocks, this option could prove to be extremely limited.[59] Demands on land of this magnitude could substantially raise food prices on basic commodities.[60] This could imperil food security for many of the world's most vulnerable, with many families

45. Makane Moïse Mbengue, *Preamble*, Max Planck Encyclopedia Pub. Int'l L., http://opil.ouplaw.com/view/10.1093/law:epil/9780199231690/law-9780199231690-e1456 (last updated Sept. 2006).
46. Vienna Convention on the Law of Treaties, *adopted* May 23, 1969, art. 31(2),1155 U.N.T.S. 331. *See also* Mbengue, *supra* note 45.
47. PA, *supra* note 1, arts. 2.2, 4.3, 4.19.
48. *See supra* note 1, arts. 4-5. *See also infra* Section II.D. (Articles 4-5).
49. *Adoption of the Paris Agreement*, Dec. 1/CP.21, UNFCCC, Annex, U.N. Doc. FCCC/CP/2015/10/Add.1 (2016) [hereinafter Paris Decision].
50. PA, *supra* note 1, arts. 2(1), 4(1), 6(1)-(2), (4), (8)-(9), 7(1), (9), 8(1), 10(5).
51. Simon Caney, *Climate Change, Human Rights, and Moral Thresholds*, *in* Climate Ethics (Stephen Gardiner et al. eds., Oxford Univ. Press 2010).
52. Maria Pia Carazo, *Contextual Provisions (Preamble and Article 1)*, *in* The Paris Agreement on Climate Change: Analysis and Commentary 115 (Daniel Klein et al. eds., Oxford Univ. Press 2017).
53. William C.G. Burns, The Paris Agreement and Climate Geoengineering Governance: The Need for a Human Rights-Based Component 1-2 (Centre for International Governance Innovation Paper No. 111, 2016), *available at* https://www.cigionline.org/sites/default/files/documents/CIGI%20Paper%20no.111%20WEB.pdf.
54. PA, *supra* note 1, arts. 7(2), 7(6), 9(c). *See also* Lavanya Rajamani, *Human Rights in the Climate Change Regime*, *in* The Human Right to a Healthy Environment (John H. Knox & Ramin Pejan eds., Cambridge Univ. Press 2018).
55. PA, *supra* note 1, pmbl. para. 14.
56. Burns, *supra* note 53.
57. Pete Smith et al., *Biophysical and Economic Limits to Negative CO_2 Emissions*, 6 Nature Climate Change 42, 46 (2016). *See also* Phil Williamson, *Emissions Reduction: Scrutinize CO_2 Removal Methods*, 530 Nature 153, 154 (2016).
58. Smith et al., *supra* note 57.
59. Ben Caldecott et al., Stranded Carbon Assets and Negative Emissions Technologies 16 (University of Oxford Smith School of Enterprise and the Environment Working Paper, 2015), *available at* https://www.smithschool.ox.ac.uk/research/sustainable-finance/publications/Stranded-Carbon-Assets-and-NETs.pdf.
60. Scott Barrett, *Solar Geoengineering's Brave New World: Thoughts on the Governance of an Unprecedented Technology*, 8 Rev. Envtl. Econ. & Pol'y 249, 254 (2014).

in developing countries already expending 70%-80% of their income on food.[61]

Impacts of this nature could contravene the human right to food provided for in many international instruments.[62] BECCS could also imperil the right to water[63] in some regions of the world given its "very large water footprint" when implemented at a scale of between 1.1 and 3.3 GT CO_2 equivalent per year.[64] By 2100, BECCS feedstock production at scale could require approximately 10% of the current evapotranspiration from all global cropland areas[65] or of the same magnitude as all current total agricultural water withdrawals.[66] Moreover, water consumption for energy generation and carbon capture could have "intensive localized effects."[67] In a world of growing food demand, this could have serious implications, as maximum crop yields are only possible under conditions where water supplies are not restricted.[68] There is also concern that BECCS operations might contaminate underground sources of drinking water.[69]

In relation to SCE, the technologies are not sufficiently developed to predict the range of potential human rights implications associated with large-scale experimentation or deployment. However, given the scale and potential impacts, such concerns will unquestionably arise. For example, sulfur aerosol injection into the stratosphere to effectuate albedo modification could substantially weaken Asian and African monsoons by substantially reducing evaporation,[70] potentially "threatening the food and water supplies of billions of people."[71] This could threaten the human rights to food and water, as well as the right to life.[72]

While a variety of climate response measures have high potential to affect human rights, the PA does not contain any action-forcing mechanism to require States to assess the human rights implications of their response measures or to publicize the potential human rights consequences of activities. There are a number of potential mechanisms that could be used to require the assessment and reporting of potential human rights consequences of climate responses, including CE, such as the NDCs, the transparency mechanism, and the global stocktake.[73]

The primary impact of the preambular language is likely to be its framing effect. As matters relating to CE arise in the context of the PA, the language provides a basis for a broader discussion on the human rights and sustainability implications of different approaches or techniques. Certainly, the IPCC in its preliminary assessment of CDR and SCE technologies in the special report on 1.5°C has shown a willingness to consider a broader scope of potential impacts, although it tends to rely on existing literature as opposed to conducting human rights assessments itself.[74]

C. *Article 2—Objectives*

Article 2 sets out the objectives of the PA, which specifies in connection with mitigation the goal of holding global average temperature increase to well below 2°C, while pursuing efforts to limit that increase to 1.5°C. The vast majority of modelled scenarios that could achieve CO_2 concentration levels consistent with the 2°C goal rely upon the use of technologies (mostly BECCS) that remove CO_2 from the atmosphere.[75] For the 1.5°C goal, even greater reliance is required.[76] For example, Sabine Fuss et al. noted that 101 of 116 of the scenarios in the IPCC's *Fifth Assessment Report* consistent with 2°C (the 430-480 parts per million pathways) require net negative emissions (that is, more CO_2 being removed from the atmosphere than is being placed into it) starting after 2050.[77] The scale of projected net negative emissions is in the order of 10-20 GT CO_2 annually by the end of the century, an amount approximately equal to 25%-50% of current CO_2 emissions.[78]

61. United Nations High Commissioner for Human Rights, Mandate of the Special Rapporteur on the Right to Food: Note on the Impacts of the EU Biofuels Policy on the Right to Food (2013), http://www.srfood.org/images/stories/pdf/otherdocuments/20130423_biofuelsstatement_en.pdf; Fifth Assessment Report, *supra* note 2, at 91; U.S. Government Accountability Office Center for Science, Technology, and Engineering, Climate Engineering 25 (2011).
62. *See*, *e.g.*, *Universal Declaration of Human Rights*, G.A. Res. 217A(III), art. 25 (1948) [hereinafter UDHR]; International Covenant on Economic, Social, and Cultural Rights, *adopted* Dec. 16, 1966, art. 11(2), 993 U.N.T.S. 3; Convention on the Rights of the Child, *adopted* Nov. 20, 1989, art. 24(2)(c), (e), 1577 U.N.T.S. 3 [hereinafter CRC].
63. *See*, *e.g.*, Convention on the Elimination of All Forms of Discrimination Against Women, *adopted* Nov. 20, 1989, art. 14(2), 1249 U.N.T.S. 13; CRC, *supra* note 62, arts. 24, 27(3); International Labour Organization Convention No. 161 Concerning Occupational Health Services, *adopted* June 25, 1985, art. 5, 71 I.L.C. Sess.
64. Smith, *supra* note 26, at 1321.
65. Smith et al., *supra* note 57, at 47.
66. Markus Bonsch et al., *Trade-Offs Between Land and Water Requirements for Large-Scale Bioenergy Production*, 8 GCB Bioenergy 11, 12 (2014).
67. Lydia J. Smith & Margaret S. Torn, *Ecological Limits to Terrestrial Biological Carbon Dioxide Removal*, 118 Climatic Change 89, 92 (2013).
68. Brian J. Legg, *Crop Improvement Technologies for the 21st Century*, *in* Yields of Farmed Species: Constraints and Opportunities in the 21st Century (R. Sylvester-Bradley & Julian Wiseman eds., Nottingham Univ. Press 2011).
69. Kelsi Bracmort & Richard K. Lattanzio, Congressional Research Service, Geoengineering: Governance and Technology Policy 12 (2013), https://fas.org/sgp/crs/misc/R41371.pdf.
70. Andy Jones et al., *A Comparison of the Climate Impacts of Geoengineering by Stratospheric SO_2 Injection and by Brightening of Marine Stratocumulus Cloud*, 12(2) Atmospheric Sci. Letters 176, 179 (2011).
71. Alan Robock et al., *Regional Climate Responses to Geoengineering With Tropical and Arctic SO_2 Injections*, 113(D16) J. Geophysical Res. 13 (2008).
72. UDHR, *supra* note 62, art. 3; International Covenant on Civil and Political Rights, *adopted* Dec. 16, 1996, art. 6(1), 999 U.N.T.S. 171.
73. Most promising perhaps is the "forum on the impact of the implementation of response measures" that was created at UNFCCC COP 24. *See* Paris Rulebook, *supra* note 7, at 29.
74. 1.5°C Report, *supra* note 4, at 342-52.
75. Thomas Gasser et al., *Negative Emissions Physically Needed to Keep Global Warming Below 2°C*, 6 Nature Comm. 7958 (2015). *See also* Sabine Fuss et al., *Betting on Negative Emissions*, 4 Nature Climate Change 850 (2014).
76. Glen Peters, *The "Best Available Science" to Inform 1.5°C Policy Choices*, 6 Nature Climate Change 646, 648 (2016); Sivan Kartha & Kate Dooley, The Risks of Relying on Tomorrow's "Negative Emissions" to Guide Today's Mitigation Action 19 (Stockholm Environment Institute Working Paper No. 2016-08, 2016), https://mediamanager.sei.org/documents/Publications/Climate/SEI-WP-2016-08-Negative-emissions.pdf.
77. Fuss et al., *supra* note 75.
78. Rogelj et al., *supra* note 2; Williamson, *supra* note 57.

The literature on the use of CDR to meet the 2°C target identifies several key challenges associated with the use of these technologies. First, there is a high level of existing uncertainty in relation to the development and implementation of the key technologies, which will require considerable research and financial support.[79] Second, as suggested above, many CDR technologies implemented at a scale contemplated to meet the PA goals may be accompanied by significant environmental, social, and economic costs. Third, managing these impacts and financing will require new governance capabilities, institutions, and regulatory frameworks.[80]

The stringent conditions for meeting the 2°C target, even with CDR, raises the prospect of global average temperatures well in excess of the Paris targets. For example, the current emission reduction pledges as contained in existing NDCs (or intended NDCs) will exceed the 2°C target, a fact acknowledged in the Paris Decision.[81] Joshua Horton, David Keith, and Matthias Honegger have indicated that uncertainty associated with climate sensitivity alone (the relationship between GHG concentrations and global average temperature) ought to give rise to further consideration of SCE technologies in order to achieve these targets.[82] Unlike CDR technologies, which are very clearly on the table at present, the degree to which SCE technologies become a central aspect of future international climate discussions will depend upon the success of the global responses contained in the PA. Despite this contingency, there appears to be a growing willingness among some countries to support further research activities in SCE to better understand the viability of these technologies.[83]

Article 2, to be clear, does not mandate or otherwise authorize CDR or SCE. Rather, the pathways to achieving these targets and the associated challenges implicate other provisions of the PA (as outlined below). As a consequence, there will be, in our view, increasing pressure on policymakers to more explicitly consider how CDR technologies factor into the Paris commitments. SCE may continue to sit uncomfortably as the elephant in the room, but one that will be harder to ignore as the challenges associated with achieving the Paris targets become more apparent, particularly if more stringent emission reduction commitments are not made in a timely fashion. Indeed, the disjuncture between national efforts and the Paris targets is powerfully stated in the IPCC's new special report on 1.5°C.[84]

Two issues related to the Paris temperature goals require further discussion. First, the presence of net negative emissions in integrated assessment models implies that for some period of time, the amount of GHGs in the atmosphere will exceed the amount of GHGs compatible with achieving the Paris temperature target of "well-below 2°C." The models "overshoot" the required atmospheric carbon budget, but then work their way back down to the desired stock of GHGs through net negative emissions.[85] A period of overshoot is of concern, as it is likely that the environmental consequences of the overshoot, such as sea-level rise or impacts on biodiversity, would not be compensated by the future CO_2 removals. A report prepared for the Convention on Biological Diversity (CBD) secretariat concluded that "the net environmental effect of adding 1 GT CO_2 and then subtracting 1 GT CO_2 only equals zero when there is no substantive de-coupling in space or time between the addition and subtraction processes. If there are decadal-scale delays, significant and potentially irreversible climatic and environmental consequences may occur."[86]

Oliver Geden and Andreas Löschel point out that despite being underlain by an approach that appears to require exceedances, the PA does not provide any direction on the duration or magnitude of the overshoot.[87] To promote greater accountability, Geden and Löschel argue that the Parties ought to agree to place constraints on the duration and magnitude of the overshoot, exclude any scenario for an overshoot of 2°C (i.e., only allow for scenarios that overshoot the 1.5°C goal), and include requirements for assessing feasibility of any relied-upon CDR technology.[88] One reading of Article 2 is that the intention of the Parties is to limit any increase to below 2°C without overshoot.

It is not clear, however, that measures to limit overshoot are implementable under the PA. Article 2 has no regulatory effect, and is only implemented through the actions taken under Articles 4 and 5, but as discussed below, there is little regulatory scope for constraining State behavior in these provisions. The global stocktake (Article 14) allows for assessment of collective issues, but again provides no mechanism for constraining State action. Addressing overshoot requires collective decisions aimed at creating clarity around how progress is assessed and communicated; these issues may be addressed through the CMA, although the precise mechanism is not clear.

The second issue concerns the provision in Article 2.2, which states, "this Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in light of different national circumstances." The use of the word "will" instead of "shall" indicates an intention to create an expectation, as opposed to an obligation, on States in

79. *See* NAS Research Agenda, *supra* note 9; NRC SCE Report, *supra* note 9.
80. Williamson, *supra* note 57; *see also* Fuss et al., *supra* note 75.
81. Paris Decision, *supra* note 49, para. 17; *see also* Emissions Gap Report, *supra* note 30; Rogelj et al., *supra* note 2.
82. Joshua B. Horton et al., Harvard Kennedy School, Belfer Center, Implications of the Paris Agreement for Carbon Dioxide Removal and Solar Geoengineering (2016), https://www.belfercenter.org/sites/default/files/files/publication/160700_horton-keith-honegger_vp2.pdf.
83. NRC SCE Report, *supra* note 9; Adrian Cho, *To Fight Global Warming, Senate Calls for Study of Making Earth Reflect More Light*, Science, Apr. 19, 2016.
84. 1.5°C Report, *supra* note 4, at 18-23.
85. Katharine L. Ricke et al., *Constraints on Global Temperature Overshoot*, 7(1) Nature Sci. Rep. 14743 (2017).
86. Williamson & Bodle, *supra* note 21, para. 109. *See also* EASAC, *supra* note 10, at 13.
87. Oliver Geden & Andreas Löschel, *Define Limits for Temperature Overshoot Targets*, 10 Nature Geoscience 881 (2017).
88. *Id.*

relation to differentiation.[89] Nonetheless, differentiation remains centrally important to the manner of the implementation of mitigation efforts as reflected in State NDCs, which allow States to determine their degree of effort in line with their development status.[90] The degree of differentiation in relation to CDR should be in line with the approach to mitigation more generally. However, because CDR decouples removals from sources both spatially and temporally, and will require significant resources, particularly land, to deliver removals at scale, there will be additional complications in determining how the burden of carbon removals is distributed among States.

One modelling exercise (using cost-optimized integrated assessment models for BECCS) showed a distribution of removal efforts that requires significant contributions from China (80 GT CO_2), India (50 GT CO_2), and Brazil (40 GT CO_2).[91] The model does not account for historic responsibility or respective capabilities, but suggests a distribution linked to other national characteristics. The significance of the exercise is that removal opportunities, like other mitigation activities, are not likely to be distributed in ways that recognize equity.[92]

While market mechanisms may provide an avenue for compensating developing countries for removal efforts, the scale of activity required and the potential impacts on development pathways and food production will require extensive further negotiation. The possibility of net negative emissions (i.e., a period where global CO_2 removals exceed emissions, bringing atmospheric levels of CO_2 back within a range consistent with the PA temperature goals) further complicates this dynamic since it requires some countries to bear the burden of removals in excess of their emissions for extended periods of time. A scenario that includes an overshoot and subsequent drawdown of CO_2 requires the long-term provision of a global public good, which typically requires incentives to maintain a stable burden-sharing arrangement, neither of which is provided for under the PA.[93]

The temperature targets in Article 2, despite their formally nonbinding nature, appear to be having indirect influences on the understanding of legally acceptable levels of harm and the consequent requirements of due diligence in customary and national law. The most prominent example is the *Urgenda* case, where the 2°C target was relied on as a basis for defining the Dutch government's duty of care.[94] The implications for CE are as yet unclear, but framing the 2°C target as a measure of the duty of care places further pressure on States to take actions toward the target, including CDR and SCE.[95] The difficulty is that both CDR and SCE present risk-risk scenarios. Thus, arguing that the customary legal obligation to prevent transboundary harm requires States to research or implement CE technologies cuts in both directions.

D. Article 3—NDCs

The fundamental architecture of the PA provides for each State to determine for itself its NDC to addressing climate change, subject to the procedural requirements of the PA. Article 3 identifies that the NDC will include a State's contributions in relation to mitigation (Article 4), adaptation (Article 7), climate finance (Article 9), technology development and transfer (Article 10), capacity-building (Article 11), and transparency (Article 13). The bottom-up architecture allows States to identify and include CE measures in their NDCs so long as they are consistent with the underlying articles. In relation to CDR, this opens the possibility of individual States integrating some CDR technologies into their reduction commitments since removals of CO_2 are expressly contemplated as an element of mitigation under Article 4 (discussed below).

There is limited scope for integration of SCE activities into NDCs, as SCE technologies are not likely to fall within the scope of NDCs as contemplated by the PA.[96] SCE cannot reasonably be characterized as mitigation, as it does not impact CO_2 levels. In addition, SCE is necessarily a collective response to climate change, a poor fit for NDCs, which are premised on individual State actions. However, as discussed below, some of the procedural mechanisms could be leveraged to promote greater transparency of State intentions and activities in relation to SCE research.

E. Articles 4 and 5—Mitigation

Article 4.1 implements the 2°C target by identifying the aim of reaching peak global GHG emissions "as soon as possible," with rapid emission reductions to follow, in order to "achieve a balance between anthropogenic emissions by sources and removals by sinks" (net emissions neutrality) after 2050. In order to achieve these objectives, States are required to pursue domestic mitigation measures as identified in their NDCs. The mitigation measures are intended to reflect each State's "highest possible ambition" and be

89. Lavanya Rajamani, *The 2015 Paris Agreement: Interplay Between Hard, Soft, and Non-Obligations*, 28 J. Envtl. L. 337, 355 (2016).
90. PA, *supra* note 1, art. 4(3).
91. Glen Peters & Oliver Geden, *Who Will Deliver the Negative Emissions Needed to Avoid 2C Warming?*, Carbon Brief, Oct. 30, 2017, https://www.carbonbrief.org/guest-post-who-will-deliver-the-negative-emissions-needed-to-avoid-2c-warming.
92. Glen Peters & Oliver Geden, *Catalysing a Political Shift From Low to Negative Carbon*, 7 Nature Climate Change 619, 620 (2017).
93. *See* Scott Barrett, Why Cooperate?: The Incentive to Supply Global Public Goods ch. 4 (2007).
94. Rechtbank Den Haag [District Court of The Hague, Chamber for Commercial Affairs], June 24, 2015, ECLI:NL:RBDHA:2015:7196 (Stichting Urgenda/Nederlanden) [Urgenda Found. v. Netherlands], https://www.elaw.org/system/files/urgenda_0.pdf. Similar arguments also appear in the United States-based *Juliana v. United States* litigation, see, for example, Brief of Amici Curiae Center for International Environmental Law & Environmental Law Alliance Worldwide-U.S., United States v. Juliana, No. 6:15-cv-01517-TC-AA (D. Or.), https://static1.squarespace.com/static/571d109b04426270152febe0/t/59af2b9bb8a79b0ce0dd8fcc/1504652189002/CIEL-ELAW+Motion+and+Amicus+Brief.pdf.
95. *See, e.g.*, Jesse Reynolds, The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene 87 (2019) (noting that the potential to argue that the duty to prevent harm could be interpreted as a positive obligation to research or implement SCE).
96. Horton et al., *supra* note 82, at 5.

progressive in their stringency over time. The wording of Article 4 is consistent with the modelling projections discussed above; namely, that attaining the 2°C target will involve a mixture of emission reductions and GHG removals. The legal issue that potentially arises is the degree to which CDR technologies, if included in NDCs, will be viewed as meeting the progressive mitigation requirements under Article 4.

The acceptability of including CDR as a mitigation option under the PA turns to some degree on the definition of "sinks." The UNFCCC definition of "sinks," which is imported into the PA by virtue of Article 1, broadly encompasses "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere." This definition, by its terms, is not restricted to naturally occurring processes. Similarly, the definition of "reservoir" includes geological and biological storage of GHGs, which would include the forms of storage contemplated by CDR technologies.

The ordinary meaning of the term "sinks" in the climate science community, again, includes any process, activity, or mechanism that removes a GHG from the atmosphere.[97] Deployment of any potential CDR would also appear to comport with the object and purpose of the UNFCCC and PA, given that the overarching objective of both treaties is to stabilize atmospheric concentrations of GHG emissions at a level that prevents "dangerous anthropogenic interference with the climate system."[98] The Vienna Convention's provisions on treaty interpretation also take into account subsequent agreements and practices of the Parties in the application of a treaty to aid in interpretation.[99] In 2011, the Parties to the UNFCCC agreed to include carbon capture and sequestration, a technology for the capture and storage of CO_2 emissions, and a component of BECCS, under the ambit of the Clean Development Mechanism of the Kyoto Protocol.[100]

On the other hand, Article 5 addresses sinks and reservoirs specifically, with the direction that Parties should "conserve and enhance" sinks and reservoirs, which might suggest an intention to limit sinks and reservoirs to natural processes. However, at the very minimum, this would not preclude the use of CDR approaches that seek to amplify natural sinks processes, including BECCS, mineral weathering on land and in the oceans, and ocean iron fertilization.

Finally, it should be noted the PA and the Paris Rulebook often use the more open-ended term "removals," sometimes in conjunction with "sinks" (i.e., "removal by sinks"), but often on its own.[101] This again suggests an intention not to distinguish between natural and engineered methods of CO_2 removal and storage.

Drawing a distinction between CDR and other forms of GHG removal on a technological basis, as the term CE as a distinct category of climate response suggests, is difficult to maintain. The concerns respecting inclusion of CDR relate less to its technological form, and more to the uncertainty and feasibility of its development, its scale, and the precision by which removals may be accounted for. From a practical standpoint, there will need to be close integration of all approaches that influence the amount of CO_2 in the atmosphere, at both domestic and international levels. As NDCs will be a central vehicle for States to communicate how their efforts will reduce atmospheric CO_2, and these will form the basis of collective assessments, separating CDR adds unnecessary complexity and may undermine transparency.

The U.S. National Academy of Sciences in a recent report on developing a CDR research agenda notes that it is likely that CDR and emission reduction methods will likely be competitors, and thus will be assessed on the basis of relative costs. As a consequence, "negative emission technologies are best viewed as a component of the mitigation portfolio, rather than a way to decrease atmospheric concentrations of CO_2 only after anthropogenic emissions have been eliminated."[102] The same report also notes that existing NDCs already include 1 GT CO_2 per year of afforestation/reforestation removals, indicating that CDR technologies are already forming part of NDCs.[103]

The question of the extent to which an unproven technology ought to be relied upon within a State's NDC is more complicated. A legitimate concern is that States might seek to justify unambitious emission reduction actions on the basis of future CDR activities. This is not an abstract concern since many of the representative concentration pathways involve emission scenarios where GHG concentrations temporarily exceed critical thresholds before being reduced to less dangerous levels. From an economic efficiency standpoint, some reliance on future CDR may be warranted, but overreliance in the face of uncertainty creates risks that NDCs may rely excessively on technologies that cannot deliver predicted results or may be viewed as socially unacceptable. One issue that we see potentially arising here is the extent to which the Parties seek to manage the balance of net emissions so as to ensure reductions are privileged over removals within NDCs.

This concern may emerge in relation to the principle of progressive commitments in NDCs, where some States and non-State actors may interpret the non-regression principle as requiring a continual reduction in emissions, as opposed to greater reliance on removals through CDR technologies. The current wording of Article 4.1 in relation to the emission neutrality goal does not indicate a minimum level of reduction commitments within the balance. Specifying such an approach might arguably undercut the bottom-

97. Fifth Assessment Report, *supra* note 2, glossary.
98. PA, *supra* note 1, art. 2(1); UNFCCC, *supra* note 3, art. 2.
99. Vienna Convention, *supra* note 46, art. 31(3)(b).
100. *Modalities and Procedures for Carbon Dioxide Capture and Storage in Geological Formations as Clean Development Mechanism Project Activities*, Dec. 10/CMP.7, UNFCCC, at 13-30, U.N. Doc. FCCC/KP/CMP/2011/10/Add.2 (2012) [hereinafter CCS Decision].
101. Compare PA, *supra* note 1, art. 4(1), with art. 4(13)-(14).
102. NAS Research Agenda, *supra* note 9, at 2.
103. *Id.* at 249.

up approach that is fundamental to the Paris architecture. While Article 4.2 requires Parties to enter into successive NDCs, and Article 4.3 requires that each successive NDC of the Parties constitutes a "progression" beyond current contributions, there is no requirement that said progression be primarily effectuated through reductions in emissions.

A supplementarity requirement that privileges emission reductions could be employed as an implementation strategy. While the dynamic is not exactly the same, concerns that overreliance on market mechanisms would lead to a de-emphasis on emissions reduction led the Parties to the Kyoto Protocol to include a requirement for Annex 1 States to use the market mechanisms in a supplemental fashion.[104] A similar approach could be adopted in relation to the balance between emission reductions and removals in NDCs, but unlike the Kyoto Protocol, there is no textual basis for supplementarity in the PA, requiring further specification by the Parties (possibly as part of the determination of the modalities, guidelines, and procedures for NDCs).[105]

An additional potential approach would be a strong reading of the call in Article 4.1 for the Parties to aim to use "best available science" to achieve rapid reductions in emissions. Similar language also appears in the Preamble to the PA ("best available scientific knowledge"). This could serve to limit NDCs to the use of well-tested technologies. It should be noted that the term "best available science" is not defined in the PA. However, in the context of environmental policymaking, such a mandate requires that policies be adopted on the basis of accurate and reliable scientific data.[106]

Reliance on unproven technologies contravenes this principle and can be viewed as a violation of the precautionary principle, although we note that the precautionary principle (a central pillar of the UNFCCC) is not expressly included in the wording of the PA. The fundamental difficulty is that the bottom-up architecture of the PA leaves the content of NDCs to the discretion of States. There is little scope for the policing of the substantive adequacy of NDCs. Consequently, the balance between removals and reductions will more likely be a matter for collective reflection under the global stocktake provision of the Agreement.[107]

Given that much of the tension that might arise in relation to CDR concerns the potential to postpone near-term emission reductions in favor of longer-term commitments to CDR, there may be a role for the "long-term low greenhouse gas emission development strategies" (LGDS) in clarifying mitigation pathways and longer-term steps necessary to ensure the feasibility of future CDR technologies.[108] The requirement for the formulation and communication of such strategies is framed as an expectation, not as an obligation (using "should" not "shall"). While Article 4.19 does not speak to removals, a number of States have developed LGDS, which reference the need to deploy CDR in order to meet long-term goals and the further need to develop CDR research and development strategies to realize those goals.[109]

LGDS have the advantage of being developed as strategic documents, potentially providing the Parties with earlier opportunities to collectively consider the direction and feasibility of States' portfolios of approaches. In effect, the LGDS may provide a link between the collective assessments under the global stocktake, and individual contributions under the NDCs, by signaling longer-term strategies and the steps being taken, such as research and development policies, to realize those strategies.

A final interpretive question that arises in relation to the inclusion of CDR technologies in NDCs is whether developing States will object to overreliance on CDR on "the basis of equity, and in the context of sustainable development and efforts to eradicate poverty" (Article 4.1). The argument here is strongly related to considerations of common but differentiated responsibilities and respective capabilities, and will depend on the degree to which the burdens associated with large-scale CDR implementation fall on developing countries and constrain development in those countries. The wording of Article 4.1 suggests that the balance between reductions and removals will need to be justified in light of developing country development aspirations, but as discussed in relation to Article 2.2, how this qualification is implemented in light of the bottom-up nature of the NDCs remains an open question.

Article 5, which addresses sinks and reservoirs, provides little additional guidance to the Parties in relation to CDR activities. As noted, the definitions of "sinks" and "reservoirs" are wide enough to encompass a variety of CDR technologies, such as BECCS, biochar, and accelerated weathering, as well as afforestation. However, Article 5.1 simply encourages States to take action. Article 5.2 incorporates existing frameworks, such as REDD+, and joint mitigation and adaptation approaches, as well as recognizing the importance of non-carbon benefits associated with such programs. While not directly applicable, the approach taken by the Parties in relation to land use and forests may provide a model for more detailed development of guidelines by the CMA for various CDR approaches. For example, the development of "safeguards" to ensure effective and sustainable development of REDD+ projects provides a useful approach that addresses many of the concerns raised in relation to CDR technologies.[110]

104. Kyoto Protocol, *supra* note 41, art. 6.1.
105. To date, the Paris Rulebook text elaborating on the requirements of NDCs does not contain any specific procedures for CDR.
106. *See* Patrick J. Sullivan et al., *Defining and Implementing Best Available Science for Fisheries and Environmental Science, Policy, and Management*, 31(9) Fisheries 460, 462 (2006).
107. *See* PA, *supra* note 1, art. 14.
108. *Id*. art. 4.19. *See also infra* Section II.J. (Article 14).
109. Nine States have lodged LGDS with the UNFCCC, see UNFCCC, *Communication of Long-Term Strategies*, https://unfccc.int/process/the-paris-agreement/long-term-strategies (last visited Oct. 20, 2019). The strategies of the Canada, the United Kingdom, and the United States all reference the need for carbon removal to address long-term goals.
110. *The Cancun Agreements: Outcome of the Work of the Ad Hoc Working Group on Long-Term Cooperative Action Under the Convention*, Dec. 1/CP.16, UNFCCC, app. 1, U.N. Doc. FCCC/CP/2010/7/Add.1 (2010).

It would be much more difficult to make a case that SCE options could constitute a form of "mitigation" for the purposes of meeting Article 4 commitments. SCE approaches clearly would not seek to limit anthropogenic emissions of GHGs. Moreover, these options do not directly seek to serve as a sink by removing CO_2 from the atmosphere or storing GHGs. While there may be indirect impacts between SCE and GHG concentration levels in the atmosphere, arguments that SCE falls within the contemplated scope of NDCs are tenuous at best. Also, as noted above, as a regulatory tool, NDCs are ill-suited to manage large-scale, collective activities, such as SCE.

F. *Article 6—Voluntary Actions*

Market mechanisms are recognized as playing a potential role in the PA, with Article 6 identifying broad mechanisms for emissions trading, referred to as "internationally transferred mitigation outcomes" (Article 6.2) and the use of offsets, through a sustainable development mechanism (Article 6.4). Negotiations on the details for implementing these mechanisms have started in the Agreement's subsidiary bodies, but the Parties have not yet agreed to implementing rules for Article 6 under the rulebook process.[111] As with Article 4, the question in relation to CE relates to the degree to which CDR technologies will be integrated into market mechanisms.

Market mechanisms will likely be a central element in the development of CDR, as the technologies are expensive, and the scale will likely require private-sector involvement. The experience with existing forms of removal (through, for example, REDD+) indicates the criticality of incentives to promote activity. The demand for including CDR technologies as part of a State's NDCs will be accompanied by a corresponding demand to integrate CDR into national and international market mechanisms. There will be a need for clear signalling of whether CDR technologies are to be integrated into global carbon markets, as there have been instances of private actors proposing and carrying out ocean fertilization experiments with a stated, but ill-conceived, objective of generating tradable carbon credits.[112] Given the potential environmental and social concerns associated with CDR implementation, it will be important to clarify these expectations for private actors.[113]

Market mechanisms facilitate the asymmetric distribution of mitigation activities in relation to mitigation responsibilities, making credibility of removals critical. The specific challenges will relate to developing reliable accounting methodologies, including addressing issues of permanence that arise in relation to carbon sequestration. As indicated above, these issues are not unfamiliar in climate regimes, as the treatment of carbon capture and sequestration under the Clean Development Mechanism has been the subject of fairly extensive technical and legal discussion.[114] However, some proposed CDR technologies, such as biochar or enhanced weathering, may present novel accounting challenges.

Given the bottom-up architecture of the PA, national and regional market rules and accounting methodologies are likely to play an important element in driving domestic and international policy on CDR development.[115] Ultimately, however, there will likely be a need for common accounting methodologies to be developed and adopted under the UNFCCC. Legal and policy disagreements over CDR could play out over the negotiation of these rules. The references in Article 6 to promoting "sustainable development and environmental integrity" provide a further invitation for the Parties to consider the social, economic, and environmental consequences of CDR.[116]

As currently conceived, market mechanisms are directed toward mitigation of emissions, but are not contemplated to address reductions in incoming solar radiation, which would be the objective in the deployment of SCE technologies. Market-based approaches will likely have little influence on the potential deployment of SCE since economic efficiency is not anticipated to be a significant barrier to deployment and private-sector involvement would be more constrained.[117] In any event, there is little scope under the PA for the development of market mechanisms to incentivize SCE development.[118] Similarly, Article 6.8 provides for the use of non-market mechanisms by the Parties to help achieve their respective NDCs, but, again, the focus is on mitigation of GHG emissions and not on reduction of incoming solar radiation.

Article 6 also calls for the development of non-market approaches to sustainable development,[119] directed toward enhanced mitigation and adaptation ambition, which could include CDR. The experimental nature of many CDR technologies means that concerted research and development efforts will need to be conducted, which will likely require public-sector support. The current cost structure of most CDR technologies is not favorable for their immediate development, but if these technologies are to be implemented at projected scales, significant efforts need to be taken now.

For example, the 2017 UNEP *Emissions Gap Report* shows gross negative emissions starting in 2030 and scaling rapidly after 2040.[120] The framework for non-market approaches remains undefined at present but could play an important role in that it is oriented toward an integrated and holistic approach. Given that many of the externali-

111. See matters relating to the PA, *supra* note 1, art. 6, and the Paris Decision, *supra* note 49, paras. 36-40.
112. *See* Craik et al., *supra* note 28.
113. *See* Oliver Geden et al., *Integrating Carbon Dioxide Removal Into EU Climate Policy: Prospects for a Paradigm Shift*, 9(4) Wiley Interdisc. Revs.: Climate Change 7-8 (2018).
114. CCS Decision, *supra* note 100.
115. Matthias Honegger & David Reiner, *The Political Economy of Negative Emissions Technologies: Consequences for International Policy Design*, 18(3) Climate Pol'y 306, 314 (2018).
116. PA, *supra* note 1, art. 6.1.
117. Horton et al., *supra* note 32, at 245-46.
118. Horton et al., *supra* note 82.
119. PA, *supra* note 1, arts. 6(8) and 6(9).
120. Emissions Gap Report, *supra* note 30, fig.7.2.

ties associated with CDR may be difficult to price, a more comprehensive approach than might be feasible through pure market mechanisms may be appropriate.

G. Articles 7 and 8

Article 7 addresses international cooperation on climate adaptation. The article recognizes adaptation as a global challenge, and provides for a number of avenues for increased cooperation, including providing for enhanced financial resources to be directed toward the adaptation efforts of developing countries (see also Article 9.4). Article 8 addresses loss and damage associated with climate change through "cooperation and facilitation" (Article 8.4). Whereas adaptation is prospective in that it seeks to avoid or minimize harmful climate impacts, the thrust of loss and damage is retrospective, focusing on impacts associated with harms that cannot be reasonably averted.[121] This distinction is blurred to some degree by the wording of Article 8.4, which includes prophylactic measures, such as early warning systems, emergency preparedness, and risk assessment as loss and damage measures.

Adaptation, as an object of regulation under the PA, is not defined under the Agreement or the UNFCCC. The IPCC, which addressed adaptation extensively in its Working Group II, defines "adaptation" as "[t]he process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects."[122]

While SCE technologies can be understood as being adaptive in a broad sense of seeking to moderate the harm from increased atmospheric GHG concentrations, the PA should not be interpreted to be addressing SCE, either in an enabling or restrictive fashion, through Article 7 or 8. As a technical matter, SCE addresses climate change itself by influencing the radiative energy balance, as opposed to the effects arising from that change.[123] In this regard, it addresses a distinct stage of climate response. In any event, the intention of the Parties was to address in-country responses to the effects of climate change, such as sea-level rise, drought, and extreme weather, not SCE.

The debates over loss and damage could, however, be more consequential for SCE. SCE technologies are oriented toward minimizing or averting the adverse effects of climate change, and the PA frames those responses as a collective responsibility. The positioning of loss and damage as a facilitative exercise, as opposed to one concerned with liability,[124] may also orient discussions toward assessment of large-scale cooperative actions, which could include SCE. There is no indication that the Warsaw International Mechanism for Loss and Damage (brought into the PA under Article 8(2)) intends to address SCE directly, but as the options for addressing loss and damage crystallize under this process, SCE options may garner increased attention.

A further question that arises is the extent to which the loss and damage provisions could be resorted to in order to address indirect adverse effects from climate change, such as those arising from CDR or SCE activities. In both cases, such effects appear to fall outside the scope of Article 8. In the case of CDR activities, the effects will be largely felt within the implementing jurisdiction, and may be assessed and mitigated by the host State. As discussed, the PA anticipates that part of the assessment of mitigation measures will include consideration of the project's specific and cumulative impact on sustainable development, including food production.

One potential avenue for addressing the adverse consequences from CDR is through the UNFCCC provision on impacts from the "implementation of response measures," which recognizes that measures taken to respond to climate change may have adverse impacts on States and may need to be addressed through collective measures.[125] There is also a reference to response measures in Article 4(15) of the PA, which provides a basis to address impacts. To date, the focus of these provisions and the work program that has emerged in relation to addressing impacts from response measures is on addressing large-scale economic transitions that flow from mitigation measures,[126] rather than the kinds of impacts that might accompany CE activities.

SCE, on the other hand, is more diffuse in its potential impacts and could involve collective or individual State decisions with adverse consequences for other States. One possible avenue to address harm from SCE activities is through international liability rules,[127] which are specifically intended to fall outside the scope of Article 8. Notwithstanding the lack of direct relevance of the loss and damage provisions for SCE governance, the approach itself, which seeks to avoid some of the attendant difficulties that liability approaches have with attribution and contribution, as well as recognize the particular vulnerabilities of developing States, may be able to provide a useful model to think about how adverse effects from SCE may be addressed.

H. Articles 9, 10, 11, and 12

The PA contains a variety of implementation and facilitation provisions addressing the facilitation of climate finance (Article 9), technology development and transfer (Article 10), capacity-building (Article 11), and education,

121. Wil Burns, *Loss and Damage and the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change*, 22(2) ILSA J. Int'l & Comp. L. 415, 416-17 (2016).
122. Fifth Assessment Report, *supra* note 2.
123. Caldeira et al., *supra* note 16.
124. Paris Decision, *supra* note 49, para. 52.
125. UNFCCC, *supra* note 3, art. 4(8); *see also* Kyoto Protocol, *supra* note 41, art. 3(14).
126. *Modalities, Work Programme, and Functions of the Forum on the Impact of the Implementation of Response Measures Under the Paris Agreement*, UNFCCC, 24th Sess., Agenda Item 4, U.N. Doc. FCCC/CP/2018/L.17 (2018).
127. *See* Horton et al., *supra* note 32.

public awareness, public participation, and access to information (Article 12). The potential impacts on CDR and SCE from these provisions are indirect in the sense that recourse could be made to these provisions to facilitate CE measures. CDR technologies, as a part of a broader mitigation response, are the most likely to be the subject of the cooperative measures anticipated in these provisions. Given the need for widespread implementation of CDR technologies, and the need for a significant increase in research on the development and potential impacts of these technologies, the measures incorporated into the PA are critical to meeting the 2°C target.

Estimates of the levels of investment needed to deploy CDR technologies at scales consistent with a 2°C range are significant. One study estimates costs associated with BECCS to be in the order of 9% of total global energy investments by 2050 (approximately $160 billion per year).[128] The allocation of significant amounts of climate finance to CDR may not be viewed by some developing countries as being in accordance with the "needs and priorities of developing countries" (Article 9.3), especially in light of the environmental and development impacts associated with CDR. On the other hand, some developing countries might consider such investments salutary if they believe that they could prevent serious climatic impacts, many of which will disproportionately affect such States. In the context of Article 9, as well as Article 6, this could facilitate developed country Parties' financing of CDR projects in developing countries as part of their obligations to effectuate mitigation.

Under Article 10, the provisions establishing a technology framework, and the associated Technology Mechanism, could support climate geoengineering research, assessment development, and technology transfer under the rubric of the Agreement. Article 10(6) provides for strengthening cooperation on technology development and diffusion, which could help ensure developing country Parties have more of a voice in the context of climate geoengineering.

A critical shortcoming associated with CDR is the disjuncture between model reliance and technological readiness; that is, climate scenarios rely on the availability of massively scaled-up CDR technologies, such as BECCS, but account poorly for the technological feasibility of deploying those technologies in environmentally and socially acceptable ways. Thus, a key governance demand is linking scenarios to realistic technology development and deployment capabilities. Both Articles 9 and 10 reference the global stocktake provisions in Article 14, which points to a potential solution to the gap between modelling scenarios and research and development activities.[129] As elaborated on below, the global stocktake provides a mechanism to consider the progress toward meeting the temperature goals, as well as accounting for financial support and technological development capabilities, allowing assessment of the technological feasibility of climate scenarios.

This process could be further facilitated by the Subsidiary Body for Scientific and Technological Advice through the development of the technology framework that is contemplated under Article 10.4, which among other considerations, is intended to include a "technological needs assessment," stakeholder engagement, and collaborative research and development activities. Among the principles under which the framework would operate is a broad commitment to coherence: "to align with the long-term vision of technology development transfer and other provisions under the PA, the existing national plans and strategies under the UNFCCC and the actions undertaken by relevant institutions of the international climate regime and beyond."[130]

Given the environmental and social concerns associated with CE, particular attention ought to be paid to Article 12, which recognizes the importance of public participation and access to information for enhancing actions under the PA.[131] Article 12 is facilitative, not directive, requiring Parties to "cooperate in taking measures." However, it could form the basis for developing a multi-State strategy for consultation and deliberation on the development and deployment of CDR technologies.

Article 12 has similar relevance for SCE. The wording of Article 12 is not restricted to mitigation or adaptation, but rather relates to "climate change," which would provide an opening for similar deliberations on SCE field research. The National Academy of Sciences in its review of SCE recommended the initiation of a deliberative process to examine the types of research governance that would be required for SCE research and the types of research that would require such governance.[132] While certain forms of small-scale research may be governed nationally, there will be a need for international cooperation, if and when experimentation scales up.

To be clear, the PA and the UNFCCC framework is one possible forum for promoting an open and scientifically informed dialogue on SCE, but it is not the exclusive forum. A "club" approach, involving a narrower group of States with interests in conducting SCE research, is an alternative approach in the near term,[133] but over time a fully inclusive governance approach, be it through the UNFCCC or another global forum, will be required given the global implications of SCE. Given the importance of SCE research developments to the broader discussions on climate responses that will arise under the PA, developing

128. Smith et al., *supra* note 57.

129. PA, *supra* note 1, arts. 9.6, 10.6.

130. *Initial Draft of the Technology Framework—Informal Document by the Chair*, UNFCCC Subsidiary Body for Scientific and Technological Advice, 48th Sess., U.N. Doc. SBSTA48.Informal.1 (2018), https://unfccc.int/resource/docs/2018/sbsta/eng/sbsta48.informal.1.pdf.

131. *See* William C.G. Burns & Jane A. Flegal, *Climate Geoengineering and the Role of Public Deliberation: A Comment on the US National Academy of Sciences' Recommendations on Public Participation*, 5 Climate L. 252 (2015).

132. NRC SCE Report, *supra* note 9, recommendation 6; *see also* Steve Rayner et al., *The Oxford Principles*, 121(3) Climatic Change 499 (2013).

133. Jon Hovi et al., *Climate Change Mitigation: A Role for Climate Clubs?*, 2 Palgrave Comm. (2016).

some mechanism by which Parties can be informed of SCE research is consistent with the overall aims of the PA and with research transparency norms.[134]

I. *Article 13*

The PA contains a dedicated transparency provision, which is intended to facilitate the monitoring, reporting, and verification of NDCs, as well as adaptation responses and support. As the transparency requirements apply specifically, inter alia, to "removals by sinks," CDR activities will likely be included in the transparency requirements, which will require the development of agreed-upon accounting methodologies.

During the Paris Rulebook negotiations, there was considerable debate respecting the degree of flexibility that would be permitted under the reporting requirements with developing States seeking greater scope to use nationally appropriate methodologies. The outcome of this debate was a single set of rules, but with some allowance for the rules to be applied with flexibility by developing States in light of their capacities.[135] High levels of methodological divergence for accounting for removals may pose a challenge, given that the different forms of carbon removal and storage currently involve high degrees of variability and uncertainty.[136]

J. *Article 14*

The global stocktake process facilitates the requirement for progression in commitments over time. The intention here is to provide a mechanism that allows the Parties to assess their progress in light of the objectives in Article 2, which will inform "updating and enhancing" NDCs. The wording in Article 14 refers to the "collective progress" of the Parties, which indicates that the global stocktake will not be used to single out individual States (transgressions will be addressed under the compliance mechanism in Article 15) but rather will assess progress from a universal perspective.

The stocktake process will account for mitigation, adaptation, and climate finance measures, and, insofar as mitigation commitments include recourse to CDR, an assessment of the efficacy of CDR approaches to contributing to the achievement of the Paris targets is likely. In particular, a key aspect of the NDCs of which the international community could take stock is the balance between emission reductions and removals through CDR technologies. The stocktake may also provide an opportunity for an assessment of the technological readiness of CDR approaches that are proposed or necessarily relied upon to achieve the Paris targets with a view to ensuring that the balance reflects technological realities, as well as concerns respecting equity and human rights.

134. Craik & Moore, *supra* note 35.
135. Paris Rulebook, *supra* note 7.
136. Lomax et al., *supra* note 17.

There is further, albeit more limited, potential for the global stocktake to address SCE research. Paragraph 100 of the Paris Decision elaborates on the potential sources of input into the global stocktake exercise (which will be determined by the CMA), which includes reports from the IPCC and subsidiary bodies. The IPCC has, in particular, shown a willingness to assess the current state of SCE and CDR research, which, if continued, might feed into the global stocktake process. The sources of input should be constructed in such a way as to allow for other international processes of CE technology assessment to inform the global stocktake, if and when they arise.

K. *The Paris Institutions*

The PA and Paris Decision identify a number of new and existing institutional bodies that will manage the Agreement over time. Chief among these is the CMA, which will be the central decisionmaking body for the Parties to implement the Agreement. As the PA itself makes no explicit mention of CE technologies, the CMA will have discretion over the development and integration of rules and processes respecting CE into the Paris framework, including the format of the NDCs (Article 4.8) and accounting guidance (Article 4.13). As noted, considerable progress on implementation rules was made at COP 24 in 2018.

The default rules of procedure for the CMA are those currently used by the COP (Article 16.5), and one expects that the Parties will continue to make decisions by consensus. Generating consensus around CE technologies, either CDR or SCE, may be a significant challenge (as evidenced by the failure of the UNEA resolution),[137] and partially explains the ambiguity around the inclusion of CDR in the PA. That said, the COP under the CBD has similar voting procedures, and has managed to craft (nonbinding) decisions on CE that have been accepted by the Parties.[138]

It is also likely that the UNFCCC's Subsidiary Bodies for Implementation and Scientific and Technological Advice, incorporated into the PA (Article 18(1)), would play a role in any consideration of CE by the regime. For example, the subsidiary bodies have recently convened a forum that is tasked, inter alia, with assessing the impacts of the implementation of climate response measures and engendering cooperation by the Parties on response strategies.[139] Under the terms of reference for the forum, it could develop guidance to the Parties and the subsidiary bodies in terms of CE, as well as facilitating ongoing sharing of information.[140]

137. *See* discussion *supra* note 8.
138. CBD COP, *supra* note 43.
139. UNFCCC, *Forum on the Impact of the Implementation of Response Measures*, http://unfccc.int/cooperation_support/response_measures/items/7418.php (last visited Oct. 20, 2019).
140. *Forum and Work Programme on the Impact of the Implementation of Response Measures*, Decs. 11/CP.21, 24, UNFCCC, U.N. Doc. FCCC/CP/2015/Add.2 (2015). *See also* Paris Rulebook, *supra* note 7, at 26.

As noted, other international conventions, such as the CBD and the London Protocol, have sought to address aspects of CE governance. However, CE technologies, including associated research activities, could potentially be addressed under a number of different regimes, such as the Vienna Convention for the Protection of the Ozone Layer (given the potential for stratospheric aerosols to impact ozone), the Convention on Long-Range Transboundary Air Pollution (again in relation to stratospheric aerosol injection), and the United Nations Convention on the Law of Sea (for marine-based geoengineering). The demand for cross-regime coordination has been recognized through the creation of the Joint Liaison Group in 2001 between the secretariats of the UNFCCC, CBD, and the Desertification Convention, which provides a forum for information-sharing and some limited joint action. Given that CE has already been the subject of regulation in other regimes, there appears to be some demand for a coordinating mechanism.

If SCE technologies do not have a clear entry point within Article 7 or 8 (nor within Article 4), the question remains whether SCE, and, particularly, more near-term questions respecting SCE research cooperation and regulation, can or should be addressed through the procedural and institutional mechanisms of the PA or left outside the framework entirely. The inclusion of loss and damage provisions in the PA signal a broader commitment to address the entire portfolio of climate responses within the context of a binding legal framework, as opposed to through nonbinding mechanisms adopted through COP decisions. Prior to the PA, the binding commitments of the Parties focused primarily on mitigation, but the scope of the matters addressed through the NDCs and through other provisions of the PA is wider.

Given the controversy surrounding SCE, there may be pressures for the UNFCCC bodies, including the PA decisionmaking bodies, to address SCE research oversight. Looking at the trajectory of ocean fertilization regulation, the prospect of field experiments in the high seas provoked resolutions from the COP of the CBD, including what amounted to a moratorium on "geo-engineering activities that may affect biodiversity," with the exception of "small-scale experiments."[141] There was a similar reaction within the London Protocol that eventually led to an amendment of the Protocol, prohibiting ocean fertilization as a form of ocean dumping, but providing for a process to authorize field experiments.[142]

There are increasing calls for atmospheric field experiments directed toward resolving uncertainties in connection with various SCE technologies, which could create increased demand for regulation under the UNFCCC and the PA. This might include a clear statement by the Parties that SCE technologies should not be deployed at a scale that could alter the climate until such time as the scientific and governance uncertainties are resolved.[143] Any mandatory regulation of SCE activities by States would require an amendment to the PA, but the Parties could take advantage of the CMA, as well as other mechanisms under the PA, to promote cooperation and transparency around SCE experimentation and to signal the international community's intention in relation to SCE deployment.

III. Conclusion

The PA signals a new approach to global climate governance that moves away from a binary distinction between developed and developing State obligations, and gives States more autonomy to determine for themselves the level and form of climate response commitment they will undertake through NDCs. The PA also consolidates a number of distinct climate responses that have been the subject of international discussion; namely, mitigation, adaptation, and loss and damage, as well as measures for implementation, under a single legal framework.

The efficacy of the PA relies on maintaining and progressively deepening ambitions to address climate change through disclosure and ongoing assessments of both efforts and impacts. These assessments will be made using the temperature targets as the chief point of reference, but also the Parties' commitments to sustainable development and respect for human rights. Within this framework, CE technologies have not been addressed as a distinct element of the portfolio of approaches to address climate change, but in the case of CDR, will necessarily be integrated into the PA's central mechanisms. SCE technologies remain largely outside the framework, and do not appear to be easily amenable to the structure and approach of the PA.

The most profound implication for CDR technologies under the PA is the potential for collective efforts to overshoot the Paris targets on the understanding that the stock of atmospheric CO_2 will be decreased to target compatible levels through future removals. The impacts of exceedances of 2°C with future reductions are not likely the same as not exceeding the 2°C target in the first place. Future guidance regarding the intentions of the Parties respecting the acceptability of overshoot scenarios is desirable, but the PA structure does not lend itself to hard prescriptions in this regard.

We are of the view that the Parties will need to grapple more directly with CDR technologies as these technologies are relied upon in NDCs. The bottom-up structure of the PA allows for States to determine for themselves whether they wish to adopt and implement CDR technologies, but there will still be considerable demand for cooperation in determining acceptable forms of accounting and reporting for CDR technologies. The potential for overreliance

141. CBD COP Decision, *supra* note 43.

142. *Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities*, *supra* note 31.

143. *See* NRC SCE Report, *supra* note 9, recommendation 3; *see also* Edward A. Parson & David W. Keith, *End the Deadlock on Governance of Geoengineering Research*, 339 Science 1278 (2013) (recommending a moratorium on large-scale SCE activities).

on future delivery of removals that may be subject to both technological and social constraints is a key concern.

While burden-sharing issues have receded in the wake of the PA, delivery of removals, particularly at net negative levels, presents formidable challenges, both in terms of equity and in providing incentives for removals. CDR opportunities are unequally distributed globally, and there is high potential for developing countries to play a significant role in delivering removals. Asking developing countries to deliver CDR for emissions that are viewed as being the historic responsibility of developed countries will likely require some form of market or other material incentives. Finally, the technology-driven nature of CDR presents risks of exacerbating a capacity divide unless there are technology-sharing and financing schemes that include CDR.

The PA institutions and procedural mechanisms, as well as the emphasis on capacity-building, transparency, and public consultation, provide a basis for future deliberations on the implementation of CDR technologies. Of particular importance are the long-term LGDS, which provide an avenue for States to signal their intentions and to provoke collective deliberations in advance of delivery. It is noteworthy that three States, Canada, the United Kingdom, and the United States, have identified the need for carbon removal in their LGDS.[144]

It is questionable whether legal regulation of SCE technologies, on the other hand, can be accommodated within the existing Paris framework. Nevertheless, the procedural mechanisms of the PA have some potential to satisfy SCE research governance demands for transparency and public deliberation. In this regard, the global stocktake may provide some opportunity to inform the Parties on the current status of SCE research, including its potential to address climate impacts and the associated risks of experimentation and deployment. Attention again needs to be paid to developing technical capacity in developing countries to assess national implications of SCE, which could potentially be addressed through Article 11.

One final consideration that the bottom-up architecture of the PA gives rise to is the increased likelihood that international cooperation on CE will reflect this decentralized structure. The legal challenge here is one of coherence and integration, as the Paris architecture makes it more likely that States will adopt multiple pathways and approaches to CE technologies, reflecting individual State interests, as well as risk preferences. The PA also relies in considerable measure on maintaining high levels of trust among the Parties, presenting a further challenge for CE, which involves novel risks and a potential realignment of material interests. As research activities generate a clearer understanding of the feasibility of CDR and SCE technologies, bringing the science to bear on the normative commitments to equity, human rights, and the nature of climate change as an issue of common concern will be critical to realizing a broader coherence to global climate policy under the PA.

144. *See* discussion *supra* note 109.