SPRAYING THE SKIES: STRATOSPHERIC AEROSOL INJECTION AND HUMAN RIGHTS

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SUMMARY

Little has been said on how the just transition to a decarbonized world relates to the human right, recently recognized by the United Nations General Assembly, to a clean, healthy, and sustainable environment. This Article explores this relationship and how to build a framework that guides current and future climate change endeavors. It argues that the human right's substantive and procedural content must incorporate just transition claims, which would help resolve whether and how to advocate for specific climate measures. One such case is stratospheric aerosol injection (SAI), a highly contested intervention where it is not clear whether it would ameliorate or aggravate climate impacts. The Article explores how to govern experimentation of this emerging technique while observing a just transition and environmental rights. If SAI is regulated and advanced within such a framework, its exploration potentially could help protect the world from the worst climate change impacts while finding more permanent mitigation and adaptation solutions.

The story begins in Baja California, Mexico, 2022. In an audacious move, a startup embarked on a controversial venture by launching weather balloons to disperse reflective sulfur particles into the stratosphere, aiming to mimic volcanic effects to combat global warming.[1] There was neither prior public engagement nor governmental authorization. This bold step into solar geoengineering, mixing entrepreneurial zeal with provocation, is part of a broader movement to research and deploy stratospheric aerosol injection (SAI) technologies. These experiments raise complex ethical, environmental, and geopolitical questions. They challenge the boundaries of scientific experimentation and global governance, sparking a heated debate on the future of climate intervention.

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1. James Temple, *A Startup Says It's Begun Releasing Particles Into the Atmosphere, in an Effort to Tweak the Climate*, MIT Tech. Rev. (Dec. 24, 2022), https://www.technologyreview.com/2022/12/24/1066041/a-startup-says-its-begun-releasing-particles-into-the-atmosphere-in-an-effort-to-tweak-the-climate/; Cassandra Garrison, *Insight: How Two Weather Balloons Led Mexico to Ban Solar Geoengineering*, Reuters (Mar. 27, 2023), https://www.reuters.com/business/environment/how-two-weather-balloons-led-mexico-ban-solar-geoengineering-2023-03-27/.

Meanwhile, global warming is knocking at our doors louder than ever.[2] The most recent and optimistic studies show that even if we stop all greenhouse gas (GHG) emissions, it will take several decades to feel the substantive effects of our actions.[3] We surely need to find alternatives to ameliorate the harshest impacts of climate change in the coming decades.[4]

In this dire context, SAI is an appealing peak-shaving technology.[5] In plain English, SAI could, if its advocates' views prove correct, buy the world some time to transi-

2. Intergovernmental Panel on Climate Change (IPCC), *Summary for Policymakers*, *in* Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II, and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 1, 4-7 (Hoesung Lee et al. eds., IPCC 2023).

3. *Id.* at 12-14; United Nations Environment Programme (UNEP), One Atmosphere: An Independent Expert Review on Solar Radiation Modification Research and Deployment 14 (2023); Jane A. Flegal et al., *Solar Geoengineering: Social Science, Legal, Ethical, and Economic Frameworks*, 44 Ann. Rev. Env't & Res. 399, 403 (2019); *see* Jeff Tollefson, *Is the 2°C World a Fantasy*, 527 Nature 436 (2015) (arguing that to limit global warming to 2 degrees Celsius (°C), the world needs to engage in broader policies to capture GHGs from the atmosphere).

4. Ocean Studies Board & National Research Council, Climate Intervention: Reflecting Sunlight to Cool Earth 177-81 (2015).

5. World Meteorological Organization (WMO), Scientific Assessment of Ozone Depletion: 2022, at 27-28 (2022) (GAW Report No. 278); Douglas G. MacMartin et al., *Solar Geoengineering as Part of an Overall Strategy for Meeting the 1.5°C Paris Target*, 376 Phil. Transactions Royal Soc'y A art. 20160454, at 11113 (2018); William C.G. Burns, *The Paris Agreement and Climate Geoengineering Governance: The Need for a Hu-*

tion into a fully decarbonized economy and society without having to suffer the most devastating climate change impacts of peak increasing temperatures.[6] SAI consists of releasing sulfur into the stratosphere to increase the reflection of solar radiation. However, there is a lot to research before its deployment.[7] Indeed, SAI is an emerging technology that lacks sufficient outdoor experimentation in the stratosphere.[8]

Relatedly, the moral hazard concerns loom large.[9] By far, "[t]he social challenge that has received the most attention is the concern that consideration, research, and development of solar geoengineering would undermine efforts to reduce greenhouse gas emissions."[10] However, it is also worth asking: What about the challenges of solar geoengineering for human rights and a just transition?[11]

SAI will not come without a cost. Ongoing discussions center on the trade offs and potential setbacks of altering the atmosphere to ameliorate the impacts of climate change.[12] For instance, there are concerns about possible side effects that altering the stratosphere could have on the ozone layer, climate patterns, and human rights.[13] The United Nations Human Rights Council (UNHRC) Advisory Committee has, therefore, called for a moratorium on experimentation "until a proper governance framework is developed."[14] Certainly, as the United Nations (U.N.) Special Rapporteur on Toxics and Human Rights warned, "[t]he climate emergency does not justify action imposing toxic burdens on people and the environment that infringe on human rights. Decarbonization and detoxification strategies should be integrated and guided by human rights principles."[15]

Meanwhile, citizens and an emerging body of literature are pushing for a just transition that considers the interests of all affected parties.[16] The core of this concept is that equity considerations must permeate regulatory frameworks and policies, leaving no one behind while transitioning to a low-carbon economy.[17] Indeed, climate change mitigation and adaptation projects are being resisted based on potential human rights impacts on local communities. "These concerns have led to questions on whether solutions to climate change are not in fact more threatening to human rights and livelihood than climate change itself."[18]

As the U.N. Special Rapporteur on Human Rights and the Environment says, "human rights should be at the heart of all climate action."[19] Accordingly, it is critical to explore the contours of what a human rights-based and just transition framework would entail for SAI endeavors.[20] This exploration becomes even more relevant given the recent recognition of the right to a clean, healthy, and sustainable

man Rights-Based Component 27 (Centre for International Governance Innovation, CIGI Paper No. 111, 2016).

6. Jochen Prantl et al., *Building Capabilities for Earth System Governance*, *in* Elements in Earth System Governance 39 (Cambridge Univ. Press 2024).
7. Stephen O. Andersen & Marco Gonzalez, Condensed Second Edition: 35th Anniversary Protecting the Ozone Layer 189 (Sally Rand ed., 2d ed. 2023); Han N. Huynh & V. Faye McNeill, *The Potential Environmental and Climate Impacts of Stratospheric Aerosol Injection: A Review*, 4 Env't Sci.: Atmospheres 114, 134-35 (2024); National Academies of Sciences, Engineering, and Medicine, Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance 191-257 (2021); Office of Science and Technology Policy, Congressionally Mandated Research Plan and an Initial Research Governance Framework Related to Solar Radiation Modification 10-43 (2023).
8. UNEP, *supra* note 3, at 11; Paul Voosen, *United States Tiptoes Into Solar Geoengineering Research*, 379 Science 628, 629 (2023).
9. *E.g.*, Jonathan Wolff, *Fighting Risk With Risk: Solar Radiation Management, Regulatory Drift, and Minimal Justice*, *in* The Ethics of "Geoengineering" the Global Climate 153 (Stephen M. Gardiner et al. eds., Routledge 1st ed. 2020); Stephen H. Schneider, *Geoengineering: Could? Or Should? We Do It?*, 33 Climatic Change 291 (1996); Mark G. Lawrence & Paul J. Crutzen, *Was Breaking the Taboo on Research on Climate Engineering Via Albedo Modification a Moral Hazard, or a Moral Imperative?*, 5 Earth's Future 136, 139 (2017).
10. Jesse L. Reynolds, The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene 29, 35-37 (1st ed. 2019).
11. *E.g.*, Chad M. Baum et al., *Public Perceptions and Support of Climate Intervention Technologies Across the Global North and Global South*, 15 Nature Commc'ns art. 2060, at 10 (2024) ("Research is therefore urgently needed which focuses on perceptions of moral hazard and mitigation deterrence in the Global South, not least as it is individuals in such countries most likely to bear the brunt of such hazards.").
12. *E.g.*, Steve Rayner et al., *The Oxford Principles*, 121 Climatic Change 499, 509-10 (2013) (concluding that "the development of a technology powerful enough to manipulate the global climate has as much potential to exacerbate existing inequalities as it does to ameliorate them"); Jennie C. Stephens et al., *The Risks of Solar Geoengineering Research*, 372 Science 1161, 1161 (2021) ("[T]he social, political, and environmental risks associated with solar geoengineering research need to be prioritized.").
13. Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment, *Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy and Sustainable Environment*, U.N. Doc. A/74/161, at 22 (July 15, 2019) [hereinafter Special Rapporteur on Human Rights and the Environment]; Toby Svoboda et al., *Climate Engineering and Human Rights*, 28 Env't Pol. 397 (2019) ("[S]hould it materialize, [climate geoengineering] will pose novel human rights challenges and may well force reconsideration of how human rights are applied as a guide to action."); National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 71-89, 105-06.
14. UNHRC, *Report of the Advisory Committee on the Impact of New Technologies Intended for Climate Protection on the Enjoyment of Human Rights*, U.N. Doc. A/HRC/54/47, at 12, 19 (Aug. 10, 2023).
15. Marcos Orellana (Special Rapporteur on the Implications for Human Rights of the Environmentally Sound Management and Disposal of Hazardous Substances and Wastes), *The Toxic Impacts of Some Proposed Climate Change Solutions*, U.N. Doc. A/HRC/54/25, at 2 (July 13, 2023) [hereinafter Special Rapporteur on Toxics and Human Rights].
16. *E.g.*, Just Transition Alliance, *Just Transition Principles*, http://jtalliance.org/what-is-just-transition/ (last visited Dec. 5, 2024); Samantha Smith et al., Just Transition: A Report for the OECD (2017); *What Is Just Transition? And Why Is It Important?*, U.N. Dev. Programme Climate Promise (Nov. 3, 2022), https://climatepromise.undp.org/news-and-stories/what-just-transition-and-why-it-important.
17. *See infra* Part II.
18. Damilola S. Olawuyi, The Human Rights-Based Approach to Carbon Finance 11 (1st ed. 2016).
19. Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment, *Right to a Healthy Environment: Good Practices*, U.N. Doc. A/HRC/43/53, at 9 (Dec. 30, 2019) [hereinafter *Right to a Healthy Environment: Good Practices*].
20. Damilola S. Olawuyi, *Advancing Climate Justice in International Law: An Evaluation of the United Nations Human Rights-Based Approach*, 11 Fla. A&M U. L. Rev. 103, 110 (2015); Daniel Bodansky et al., International Climate Change Law 298-99 (1st ed. 2017); Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy and Sustainable Environment, *Report of the Special Rapporteur*, U.N. Doc. A/HRC/37/59, at 5 (Jan. 24, 2018) [hereinafter *Report of the Special Rapporteur*] ("[M]ore work is necessary to clarify how human rights norms relating to the environment apply to specific areas."); *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *in* Climate Geoengineering: Science, Law, and Governance 117 (Wil Burns et al. eds., Springer 1st ed. 2021) ("[A] human rights framework can be understood as a descriptive theory, anticipating legal and political reactions to negative deployment impacts.").

environment ("the right to a healthy environment") at the U.N. General Assembly (UNGA) in 2022. However, there is insufficient analysis on how the substantive and procedural content of the right to a healthy environment could shape the research and deployment of SAI. More generally, there is a lack of research on "transition dynamics and the flexibility of institutions to drive towards low-carbon development pathways."[21]

Thus, the first question to answer is: What is a just transition? This expansive concept finds widespread application beyond the labor movement across the environmental, energy, natural resources, and human rights domains.[22] From this analysis, I then investigate its relationship to the right to a healthy environment. This research is especially important since there is also a lack of research on the connections between the recently recognized right and the just transition perspective.

Through these lenses, I suggest a new operational framework under the right to a healthy environment and just transition to analyze the legal challenges of SAI research and deployment. In particular, I focus on the lack of a governing body, the role of public engagement, environmental impact assessment (EIA), and environmental law principles. Such analysis is conducted under an international law perspective, given its potential global impacts.[23]

The aim of this operational framework is to evaluate the legitimacy of SAI by offering a legal construct to discuss the concerns around it.[24] In particular, I offer a potential pathway to guide the discussion around its development from an institutional legal perspective, utilizing a human rights-based and just transition framework.[25] Nevertheless, in this Article, I do not endorse SAI.

Consequently, I refrain from delving into the ethical and philosophical debates regarding which approach to adopt when balancing human rights in SAI research and deployment.[26] I am more concerned about laying broader connections between the human right to a healthy environment, the just transition movement, and the operation of SAI and similar technologies. For these reasons, I concentrate on institutional dilemmas revolving around SAI, such as whether and how to regulate research, experimentation, and deployment; how SAI relates to international environmental law principles; what public engagement should look like; and environmental and human rights impact assessment (HRIA) mechanisms.

The Article is structured as follows. First, Part I explains the development of SAI technologies and highlights its environmental and transboundary issues. Part II addresses the contours of the just transition concept, and differentiates it from the environmental, energy, and climate justice perspectives. Part III investigates the human right to a healthy environment and the legal implications of its recognition by UNGA.

Part IV explores connections between a just transition framework and the human right to a healthy environment for a broader analytical framework of climate change policies. It also delves into the human rights-based approach and its relevance to SAI research and deployment, exploring what a right to a healthy environment would entail in this context. Part V applies this nascent operational framework to address four SAI deployment challenges, and then draws conclusions based on that application and analysis. Part VI concludes.

I. Stratospheric Aerosol Injection

"There are many ironies that surround our response to climate action. For instance, the most significant public works engineering projects of the twenty-first century are likely to be aimed at correcting the environmental damage of the major public works engineering projects of the twentieth century."[27] Indeed, SAI is possibly one such public works engineering project, which in turn could become a solution that creates new problems to be solved.

A. What Is SAI?

Geoengineering refers to a wide array of technological and methodological tools to modify the climate and ameliorate climate change impacts.[28] The main methods focus on reducing the solar energy absorbed by increasing its reflection (solar radiation modification or SRM) or on augment-

21. IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 191 (P.R. Shukla et al. eds., 2022).
22. Ann M. Eisenberg, *Just Transitions*, 92 S. Cal. L. Rev. 273, 278 (2019).
23. Reynolds, *supra* note 10, at 3; Flegal et al., *supra* note 3, at 409.
24. *E.g.*, Marco Grasso, *Sulfur in the Sky With Diamonds: An Inquiry Into the Feasibility of Solar Geoengineering*, 10 Glob. Pol'y 217, 223-24 (2019) (arguing that to favor the technological and political practicability of solar geoengineering, the inclusion and observance of procedural justice concerns, as well as of distributive justice, would be critical, increasing its legitimacy before citizens, policymakers, and other stakeholders); Flegal et al., *supra* note 3, at 413; Peter C. Frumhoff & Jennie C. Stephens, *Towards Legitimacy of the Solar Geoengineering Research Enterprise*, 376 Phil. Transactions Royal Soc'y A art. 20160459, at 9 (2018).
25. *See* Judith Kreuter, Climate Engineering as an Instance of Politicization 5 (1st ed. 2021) (This should be nuanced under the opinion that "it is important to assess whether, in this situation of little political decision-making, meanings of CE [climate engineering] constructed in the much larger academic discussion might be drawn into this void, thus pre-defining the decision by inadvertently legitimizing or delegitimizing this set of approaches as a measure to address climate change.").
26. *E.g.*, Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks 11-77 (Will C.G. Burns & Andrew L. Strauss eds., Cambridge Univ. Press 1st ed. 2013); *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 133-41; Audrey Chapman & Jessica Wyndham, *A Human Right to Science*, 340 Science 1291 (2013); Lea Shaver, *The Right to Science and Culture*, 2010 Wis. L. Rev. 121 (2010) [hereinafter *The Right to Science and Culture*]; Lea Shaver, *The Right to Science: Ensuring That Everyone Benefits From Scientific and Technological Progress*, 4 Eur. J. Hum. Rts. 411 (2015).
27. *Climate Action: The Feasibility of Climate Intervention on a Global Scale*, *in* Climate Geoengineering: Science, Law, and Governance, *supra* note 20, at 85.
28. 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 89 (Rajendra K. Pachauri et al. eds., 2014).

ing the absorption or removal of carbon dioxide (carbon dioxide removal or CDR).[29]

SRM concentrates on lessening solar radiation impacts to change the climate system without altering GHG concentrations.[30] While not addressing the root causes of climate change, it seeks to reduce the solar heat reaching the earth's surface, thereby reducing heat effects on human societies and ecosystems. As such, the Intergovernmental Panel on Climate Change (IPCC) does not consider SRM as a mitigation or adaptation measure.[31] Indeed, the World Meteorological Organization (WMO) clearly differentiates SAI technologies from mitigation efforts by emphasizing that SAI can only reduce surface temperatures; it would not restore past climate conditions.[32] Still, SRM is emerging as a feasible approach to reduce global temperatures in the short term, while substantive solutions are implemented.[33]

Basically, there are three types of SRM technologies. The first is cirrus cloud thinning, which aims to reduce the number of high cirrus clouds trapping infrared radiation from the earth, allowing the radiation to go out to space.[34] The second type is marine cloud brightening, which looks to "increase the amount of sunlight reflected to space by low clouds in the marine atmosphere."[35]

The third type is SAI. SAI is a proposed geoengineering technique involving the deliberate release of particles into the earth's stratosphere from aircraft to reflect sunlight and thus partially offset surface warming.[36] Out of the three, SAI is one of the most promising technologies to reduce a dramatic increase in global temperatures, based on its scalability, cost benefit, and effectiveness.[37] SAI is considered a "last-ditch protective measure"[38] to peak-shave the highest temperature increases in the coming decades.[39] This technology is being widely discussed in many forums, such as at the most recent meeting of the Parties (MOP) of the Montreal Protocol on Substances That Deplete the Ozone Layer (Montreal Protocol) in late 2023 and the sixth session of the U.N. Environment Assembly (UNEA-6) in early 2024.[40]

Despite the resistance to SAI research, there are increasing initiatives to promote experimentation.[41] For instance, in February 2024, the World Climate Research Programme, cosponsored by the International Science Council, launched the Lighthouse Activity on Climate Intervention Research.[42] This initiative aims to develop "rigorous, transparent, and globally inclusive research . . . required to further understand and facilitate the comprehensive assessments that are needed to inform climate policies."[43]

B. *Environmental Concerns*

"SRM experiments present a new kind of global problem: never before has the world collectively decided whether to conduct experiments that could affect so many people's welfare in such significant ways."[44]

As the IPCC states, when it comes to SAI "[s]cale and intent are of central importance."[45] Indeed, the potential environmental impacts of SAI technologies are closely related to its physical extension. As of 2025, SAI remains largely untested, so there is little understanding of the specific positive or negative consequences it could have on the environment.[46] Certainly, SAI requires more examination.[47]

Since SAI is an emerging technique, there are many levels of experimentation studies. The strategies can be indoor research, small-scale process-oriented outdoor experimentation, and large-scale SAI experimentation. Each of these experimental studies carries different regulatory and environmental challenges, with outdoor large-scale experimentation facing increasing public opposition.[48]

In this vein, a previous technology that also faced similar constraints was the research on genetically modified organisms (GMOs), especially for agricultural produc-

29. *Id.*; IPCC, *Annex I: Glossary*, *in* Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II, and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 129 (H. Lee et al. eds., IPCC 2023).
30. UNHRC, *supra* note 14, at 23; William Morrissey, *Avoiding Atmospheric Anarchy: Geoengineering as a Source of Interstate Tension*, 2 Env't & Sec. 291 (2024).
31. IPCC, Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Geoengineering 2 (Ottmar Edenhofer et al. eds., 2012).
32. WMO, *supra* note 5, at 331.
33. UNEP, *supra* note 3, at 10.
34. IPCC, *supra* note 31, at 2.
35. UNEP, *supra* note 3, at 12.
36. *Id.* at 11.
37. IPCC, *supra* note 28, at 89; WMO, *supra* note 5, at 336; UNEP, *supra* note 3, at 11.
38. Steven Pinker, Enlightenment Now: The Case for Reason, Science, Humanism, and Progress 152 (2018).
39. *See* WMO, *supra* note 5; MacMartin et al., *supra* note 5; Burns, *supra* note 5.
40. *See* Montreal Protocol Decision XXXV/4: Stratospheric Aerosol Injection and Protection of the Ozone Layer (2023).
41. Paul J. Crutzen, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?*, 77 Climatic Change 211, 217 (2006); Ocean Studies Board & National Research Council, *supra* note 4, at 9; John G. Shepherd, Geoengineering the Climate: Science, Governance, and Uncertainty ix (2009); Voosen, *supra* note 8, at 628.
42. Hindumathi Palanisamy, *World Climate Research Programme Launches a Lighthouse Activity on Climate Intervention Research*, Int'l Sci. Council (Feb. 15, 2024), https://council.science/current/blog/world-climate-research-programme-launches-a-lighthouse-activity-on-climate-intervention-research/.
43. *Id.*
44. *Political Legitimacy in Decisions About Experiments in Solar Radiation Management*, *in* Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks, *supra* note 26, at 152.
45. IPCC, *supra* note 28, at 123; UNEP, *supra* note 3, at 10.
46. IPCC, *supra* note 28, at 89; UNEP, *supra* note 3, at 15; Frank Biermann et al., *Solar Geoengineering: The Case for an International Non-Use Agreement*, 13 WIREs Climate Change e754, at 2-3 (2022); Peter J. Irvine et al., *Towards a Comprehensive Climate Impacts Assessment of Solar Geoengineering*, 5 Earth's Future 93 (2017).
47. WMO, *supra* note 5, at 336; Crutzen, *supra* note 41, at 211-12.
48. John Fialka & E&E News, *Pandemic Leads Geoengineering Experiment to Move From U.S. to Sweden*, Sci. Am. (Dec. 17, 2020), https://www.scientificamerican.com/article/pandemic-leads-geoengineering-experiment-to-move-from-u-s-to-sweden/; *Why Did the Saami Council Oppose Harvard's SCoPEx Experiment?*, C2G (Dec. 12, 2022), https://www.c2g2.net/asa-larsson-blind/.

tion.[49] GMOs "are crops and other organisms that have been genetically modified by use of recombinant DNA technologies and food and other products containing such organisms."[50] Given the potential environmental and health risks GMOs pose, the Parties to the Convention on Biological Diversity (CBD) negotiated in the 1990s the Cartagena Protocol on Biosafety to the CBD.[51] This protocol was established with the aim to ensure

> an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.[52]

Thus, there are many analogies to draw from experiences with GMOs when considering SAI. For instance, the precautionary principle has shaped regulatory approaches to GMO use, such as the Cartagena Protocol.[53] Additionally, the precautionary principle is also emerging as a key regulatory mechanism in the SAI case.[54]

Another analogy would be the ongoing discussions surrounding international governance in regulating the research and development of new technologies.[55] For instance, there are similar discussions on the authority of international governance bodies, the circumstances of developing countries, or the role of scientists.[56] Still, after enacting restrictive GMO regulatory frameworks in the European Union, for example, there is disagreement on whether restricting GMOs was the result of scientific research or whether this decision was deeply influenced by political interests and public pressure.[57]

Going back to SAI, there are two main environmental concerns. First, that these methods deliberately alter entire climate systems such as the atmosphere or the oceans.[58] Second, that SAI could produce massive transnational or global environmental impacts.[59] Consequently, there are widespread concerns about decreasing global precipitation or ozone degradation in polar zones.[60] Moreover, if future deployed SAI technologies ceased to operate, it could cause a rapid surface temperature increase.[61] Indeed, further research is necessary to determine whether, after discontinuing the injection of aerosols into the stratosphere, the temperature and environmental impacts would escalate back to pre-intervention levels. This scenario has been identified as the "termination risk."[62]

Thus, while SAI aims to reduce global temperatures, it may also trigger significant environmental impacts. In fact, "it would imply spatial and temporal redistributions of risks."[63] These potential unintended consequences could undermine the right to a healthy environment and other human rights. As Jesse Reynolds speculates, "[c]ould solar geoengineering help protect people's substantive human rights from climate change's impacts, or might it undermine these rights? If the former, should they research, develop, and even implement solar geoengineering? If the latter, should states cooperate to prevent these activities?"[64] In this Article, I contribute to the discussion on regulating SAI by arguing for inclusion of a focus on just transition goals and principles.

II. A Just Transition

This part serves to clarify what entails a just transition. Then, it applies its central precepts to SAI and considers how it should be investigated by incorporating public input, among other considerations.[65] Just transition approaches are differentiated on "the kind of transition they argue for, the inclusivity of their scope and scale, their approach to participation and the justice perspectives they incorporate,"[66] among other factors. Thus, the confusion increases as just transition meanings grow in number and type. I begin by narrowing down the concept, examining contemporary literature from the law and public policy fields.

49. Theofanis Christoforou, *The Regulation of Genetically Modified Organisms in the European Union: The Interplay of Science, Law, and Politics*, 41 Common Mkt. L. Rev. 637, 637 (2004).
50. Dorothy Nelkin et al., *The International Challenge of Genetically Modified Organism Regulation*, 8 N.Y.U. Env't L.J. 523, 523 (1999).
51. Cartagena Protocol on Biosafety to the CBD, May 16, 2000, S. Treaty Doc. No. 30619, 2226 U.N.T.S. 208.
52. *Id.* art. 1.
53. Anne Ingeborg Myhr & Terje Traavik, *The Precautionary Principle: Scientific Uncertainty and Omitted Research in the Context of GMO Use and Release*, 15 J. Agric. & Env't Ethics 73, 74 (2002); Nassim Nicholas Taleb et al., *The Precautionary Principle (With Application to the Genetic Modification of Organisms)* 1-10 (New York University School of Engineering, Working Paper, 2014); World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), The Precautionary Principle 27 (2005). *See infra* Section V.A.1.
54. *See infra* Section V.A.1.
55. *E.g.*, Maria Weimer, *Risk Regulation and Deliberation in EU Administrative Governance—GMO Regulation and Its Reform*, 21 Eur. L.J. 622, 622-24 (2015); Rebecca M. Bratspies, *Is Anyone Regulating?: The Curious State of GMO Governance in the United States*, 37 Vt. L. Rev. 923, 923-30 (2012); Jennifer Kuzma, *Properly Paced? Examining the Past and Present Governance of GMOs in the United States*, *in* Innovative Governance Models for Emerging Technologies 176, 176-79 (Gary E. Marchant et al. eds., Edward Elgar Publishing 2013). *See infra* Section V.3.
56. Nelkin et al., *supra* note 50, at 525-26.
57. John Davison & Klaus Ammann, *New GMO Regulations for Old: Determining a New Future for EU Crop Biotechnology*, 8 GM Crops & Food 13, 22-23 (2017).
58. IPCC, *supra* note 28, at 123.
59. *Id.*
60. WMO, *supra* note 5, at 360-63.
61. IPCC, *supra* note 28, at 89.
62. WMO, *supra* note 5, at 361; Huynh & McNeill, *supra* note 7, at 134.
63. IPCC, *supra* note 28, at 89.
64. Reynolds, *supra* note 10, at 113.
65. Eisenberg, *supra* note 22, at 275; Dimitris Stevis & Romain Felli, *Green Transitions, Just Transitions*, 3 Kurswechsel 35, 35 (2016); Xinxin Wang & Kevin Lo, *Just Transition: A Conceptual Review*, 82 Energy Rsch. & Soc. Sci. art. 102291, at 2 (2021); Alexandra R. Harrington, Just Transitions and the Future of Law and Regulation 4-7 (1st ed. 2022); Raphael J. Heffron, Achieving a Just Transition to a Low-Carbon Economy 9-10 (2021).
66. Vilja Johansson, *Just Transition as an Evolving Concept in International Climate Law*, 35 J. Env't L. 229, 230 (2023); Lisa Baumgartner & Sangji Lee, U.N. Development Programme, How Just Transition Can Help Deliver the Paris Agreement 8 (Kate Jean Smith ed., 2022).

Broadly speaking, the "just transition" term is used in two ways. First, from a labor perspective, just transition is applied to address the relation between environmental and labor concerns.[67] Second, the term is used as a normative framework that calls for incorporating equity considerations while transitioning to a low-carbon economy.[68] Still, both concepts are built from intertwined factors.[69]

A. A Labor Just Transition Perspective

At first, the term "just transition" emerged from a labor perspective.[70] During the 1970s, U.S. labor unions of displaced industries that did not meet the environmental standards imposed by the government were concerned about their jobs.[71] The Oil, Chemical, and Atomic Workers Union suggested developing a superfund to retrain workers and increase community support, which was finally named a "just transition proposal."[72] Hence, from its origins, the labor-oriented just transition approach merged the economic perspective with the advance of environmental protection, keeping a labor focus.[73]

Certainly, this labor-oriented concept embraces the move from a fossil fuel-based economy.[74] However, this just transition approach concentrates on mitigating the adverse economic impacts borne by workers and communities that relied on fossil fuel-based economies, but now face economic adversity with shifts away from carbon-based fuels.[75] In this regard, the just transition concept has been championed by the International Labour Organization (ILO), a U.N. agency.[76]

For instance, the "Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies for All,"[77] published by the ILO, are among the documents standardizing means to achieve a just transition.[78] In this document, the ILO already starts expanding the labor concept by embracing a just transition concept that considers economic, social, environmental, and labor factors, by moving "towards environmentally sustainable and inclusive economies and societies."[79]

Another organization that has been essential in championing this labor-based understanding is the International Trade Union Confederation (ITUC).[80] The ITUC has proved influential in pushing the labor concept in the international environmental arena. For instance, the ITUC was essential for incorporating the just transition concept in climate change venues such as the U.N. Framework Convention on Climate Change (UNFCCC).[81]

B. A General Just Transition Perspective

Since the 1990s, the understanding of just transition moved from a strict labor-setting idea into a general approach for society,[82] including utilizing wider environmental and climate contexts.[83] This global move expanded the boundaries of the labor-based concept into the distribution of broader benefits and burdens of shifting away from a fossil fuel economy.[84] This just transition perspective advocates comprehensive systemic changes through a series of "highly contested socio-political processes."[85] Still, there is no single agreed-upon definition of what a just transition means.[86]

As many institutions and scholars posit, a just transition is a framework that promotes

> a set of principles, processes and practices aimed at ensuring that no people, workers, places, sectors, countries or regions are left behind in the move from a high-carbon to a low-carbon economy. It includes respect and dignity for vulnerable groups; creation of decent jobs; social protection; employment rights; fairness in energy access and use and social dialogue and democratic consultation with relevant stakeholders.[87]

Throughout this Article, I embrace this just transition concept.

Consequently, the call for a just transition is made in settings as diverse as food justice to energy sovereign-

67. Eisenberg, *supra* note 22, at 280.
68. *See* Mark Swilling, The Age of Sustainability: Just Transitions in a Complex World 196 (2020); Eisenberg, *supra* note 22, at 280.
69. Eisenberg, *supra* note 22, at 280.
70. Becca Wilgosh et al., *When Two Movements Collide: Learning From Labour and Environmental Struggles for Future Just Transitions*, 137 Futures 102903 (2022); Wang & Lo, *supra* note 65, at 2; Peter Newell & Dustin Mulvaney, *The Political Economy of the "Just Transition,"* 179 Geographical J. 132, 133 (2013).
71. Eisenberg, *supra* note 22, at 285; Damian White, *Just Transitions/Design for Transitions: Preliminary Notes on a Design Politics for a Green New Deal*, 31 Capitalism Nature Socialism 20 (2020).
72. Wang & Lo, *supra* note 65, at 2; Eisenberg, *supra* note 22, at 286; Anabella Rosemberg, *Building a Just Transition: The Linkages Between Climate Change and Employment*, 2 Int'l J. Labour Rsch. 125, 143-45 (2010).
73. *E.g.*, Smith et al., *supra* note 16; Rosemberg, *supra* note 72, at 141.
74. *E.g.*, Chrislain Eric Kenfack, Changing Environment, Just Transition, and Job Creation: Perspectives From the South (2018) (analyzing the One Million Climate Jobs Campaign developed by South Africa under the context of a just transition to low-carbon economies).
75. Newell & Mulvaney, *supra* note 70, at 134; Wang & Lo, *supra* note 65, at 3.
76. Harrington, *supra* note 65, at 20.
77. ILO, Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies for All (2015).
78. Harrington, *supra* note 65, at 33-34.
79. ILO, *supra* note 77, at 6.
80. Rosemberg, *supra* note 72, at 141-42.
81. *See* Adrien Thomas, *Framing the Just Transition: How International Trade Unions Engage With UN Climate Negotiations*, 70 Glob. Env't Change 102347 (2021).
82. Newell & Mulvaney, *supra* note 70, at 133; Maria Soledad C. de Leon, Just Transition: Electric Distribution Utilities Heading Into a Decarbonizing World 16 (May 6, 2022) (Ph.D. thesis, Georgetown University); Harrington, *supra* note 65, at 21; Baumgartner & Lee, *supra* note 66, at 8.
83. White, *supra* note 71, at 4; Wang & Lo, *supra* note 65, at 2-3; Swilling, *supra* note 68, at 196; IPCC, *supra* note 21, at 75.
84. Eisenberg, *supra* note 22, at 286; de Leon, *supra* note 82, at 15-19.
85. Swilling, *supra* note 68, at 196, 321; *e.g.*, Nqobile Xaba & Saliem Fakir, A Just Transition to a Low Carbon Future in South Africa 2-3 (2022) (introducing some of the key transformational changes to achieve a just transition); Tara Righetti, *Just Transitions in Extractive Territories*, *in* The Power of Energy Justice & the Social Contract 227, 229-30 (Raphael J. Heffron & Louis De Fontenelle eds., Springer Nature 2024) (analyzing the necessary changes around mineral extraction areas for a just energy transition).
86. Wang & Lo, *supra* note 65, at 2.
87. IPCC, *supra* note 21, at 75; Baumgartner & Lee, *supra* note 66, at 8.

ty.[88] Certainly, the focus goes beyond fossil fuel workers, expanding under a justice notion that comprehends race, gender, class, and political considerations, to name a few.[89] For example, in the climate change sphere, just transition principles are used to identify strategies to lessen the disparate socioeconomic effects of climate policy on vulnerable groups.[90] Thus, a broad just transition concept could prove essential for advancing a framework for an equitable deployment of geoengineering technologies.[91]

While some continue to argue for a narrow labor-based concept,[92] others push for the broader one.[93] Critics of the labor concept state that it only focuses on fossil fuel workers, unemployment, and retraining.[94] In contrast, an expansive use of the just transition concept would include wider environmental, energy, and climate justice concerns for deeper structural changes.[95]

A recent example illustrating the evolving use of just transition arose in connection with the UNFCCC and its recent Conferences of the Parties (COPs).[96] First, there was a narrow labor-based concept in the preamble of the Paris Agreement resulting from COP21 of the UNFCCC in 2015, which takes "into account the imperatives of a just transition of the work force and the creation of decent work and quality jobs in accordance with nationally defined development priorities."[97] As a result, successive updates of nationally determined contributions (NDCs) have incorporated just transition mentions.[98] Further developments included just transition declarations during COP24 in 2018[99] and COP26 in 2021.[100]

More recently, during COP28 in late 2023, the COP to the Paris Agreement achieved a significant breakthrough by agreeing to implement a work program to facilitate just transition pathways to achieve the goals outlined in the Paris Agreement.[101] However, this work program embraces a broader notion of what a just transition means, beyond the labor concerns. Indeed, from a procedural standpoint, the implementation of this work program must prioritize international cooperation and inclusive, participatory approaches.[102] This approach represents a significant advancement toward more horizontal strategies in policymaking, as opposed to top-down approaches.

Still, the idea that the work program incorporates a broader just transition perspective is clearer in its substantive provisions.[103] First, on the labor-based approach, the agreement stipulates inclusion of a just transition for the work force within the program.[104] This agreement entails calling for the availability of decent jobs, fostering social dialogue, and upholding labor rights.[105] Second, concerning the general just transition approach, the program underscores the necessity of a fair and equitable transition across all dimensions, including energy and socioeconomic impacts.[106] This comprises implementing social protection measures to mitigate any adverse effects stemming from such transitions.[107] Finally, the agreement mandates the inclusion of opportunities and challenges related to sustainable development and poverty eradication among transitioning countries.[108] It also emphasizes the incorporation of approaches to enhance climate change adaptation and resilience.[109]

This work program represents the international ambition to flesh out what a just transition means considering the imperatives of the just transition in climate change policies, as stated in the Paris Agreement preamble.[110] One of its most prominent features is its acknowledgment of a broader just transition concept, extending beyond labor considerations to encompass all dimensions of transitioning economies. This program and its future implementation enrich the evolving just transition framework among climate change policies, and it could be a key report to consider in following climate technology endeavors.

88. Matthew S. Henry et al., *Just Transitions: Histories and Futures in a Post-COVID World*, 68 Energy Rsch. & Soc. Sci. 101668, 101668 (2020); Wang & Lo, *supra* note 65, at 3; Smith et al., *supra* note 16, at 2-4; Just Transition Alliance, *supra* note 16 (The Just Transition Alliance has also developed six broad principles for a just transition, which range from labor concerns to sustainable development and a clean environment.).
89. Wang & Lo, *supra* note 65, at 8; Aarón Atteridge & Claudia Strambo, Stockholm Environment Institute, Siete Principios Para Una Transición Justa Hacia Una Economía Baja En Carbono 6 (2021); Noel Healy & John Barry, *Politicizing Energy Justice and Energy System Transitions: Fossil Fuel Divestment and a "Just Transition,"* 108 Energy Pol'y 451, 452 (2017); IPCC, *supra* note 21, at 473.
90. Johansson, *supra* note 66, at 230.
91. *See infra* Section II.C, Parts V and VI.
92. Tonia Novitz, *Engagement With Sustainability at the International Labour Organization and Wider Implications for Collective Worker Voice*, 159 Int'l Labour Rev. 463, 466-75 (2020).
93. Eisenberg, *supra* note 22, at 286-87.
94. White, *supra* note 71; J. Mijin Cha et al., *Environmental Justice, Just Transition, and a Low-Carbon Future for California*, 50 ELR 10216 (Mar. 2020), https://www.elr.info/articles/elr-articles/environmental-justice-just-transition-and-low-carbon-future-california; Wang & Lo, *supra* note 65, at 7-8; Harrington, *supra* note 65, at 20.
95. Newell & Mulvaney, *supra* note 70, at 133, 135, 137-38.
96. *See also* IPCC, *supra* note 21, at 76 (recounting many other examples from different States around the world to develop just transition commissions, task forces, and dialogues).
97. Paris Agreement to the UNFCCC pmbl., Dec. 12, 2015, T.I.A.S. No. 16-1104.
98. IPCC, *supra* note 21, at 24-33.
99. COP24 UNFCCC, Solidarity and Just Transition Silesia Declaration (2018).
100. Government of the United Kingdom et al., UN Climate Change Conference UK 2021: Supporting the Conditions for a Just Transition Internationally (2021).
101. COP28 UNFCCC, Decision -/CMA.5: United Arab Emirates Just Transition Work Programme (Advance Unedited Version) (2023); *see also* Setenay Hizliok & Antonina Scheer, *What Is the Just Transition and What Does It Mean for Climate Action?*, Grantham Rsch. Inst. (Feb. 20, 2024), https://www.lse.ac.uk/granthaminstitute/explainers/what-is-the-just-transition-and-what-does-it-mean-for-climate-action/ (recounting the latest developments on just transition at the international, regional, domestic, and private levels).
102. COP28 UNFCCC, *supra* note 101, §2.
103. *Id.*
104. *Id.*
105. *Id.*
106. *Id.*
107. *Id.*
108. *Id.*
109. *Id.*
110. *See* Paris Agreement to the UNFCCC pmbl., Dec. 12, 2015, T.I.A.S. No. 16-1104.

C. *A Just Transition Trifecta*

The just transition concept is increasingly prevalent in the literature on environmental, energy, and climate justice.[111] Could this be the just transition trifecta?[112] As previously stated, a just transition can be defined from a broad perspective as a framework of principles, processes, and practices that ensure an equitable transition to a decarbonized economy.[113] Many authors discuss whether just transition criteria could work as a comprehensive framework for integrating the emerging justice concerns in these three fields.[114]

Indeed, the environmental, energy, and climate justice arenas raise distributive and procedural justice questions, which could be enriched under the umbrella of the just transition concept.[115] A future operational framework for climate engineering technologies could also benefit from the ongoing development of these fields. Here, I turn to a few ways in which the just transition and environmental, energy, and climate justice goals coexist in a symbiotic relationship.

Let us first attend to environmental justice concerns, which arise from the claim that injustice is often the reality faced by vulnerable communities, who bear a disproportionate distribution of environmental burdens.[116] Thus, advocates for broad incorporation of environmental justice sensitivity and corrective measures argue that "all citizens should be equally involved in the development, implementation, and enforcement of environmentally just policies."[117] However, environmental justice has been criticized for not addressing socioeconomic impacts like job security and economic equity.[118] Thus, scholars are increasingly focusing on these consequences, bringing environmental justice closer to the broad concept of just transition.[119]

On the other hand, calls for energy justice aim to build an energy system that embraces a more equitable distribution of its costs and benefits and more participative and inclusive decisionmaking processes and outcomes, such as access to affordable and reliable energy.[120] Like environmental justice writings and advocacy, some of the shortcomings of energy justice are that its lens does not fully include the socioeconomic perspective, such as issues related to spatial justice.[121] Spatial justice refers to how geographical factors influence inequity and injustice in the energy field.[122]

For instance, energy poverty manifests differently in specific regions or communities.[123] The just transition framework could complement energy justice work by expanding its public engagement with other nonexpert stakeholders, such as local and Indigenous communities.[124] Moreover, scholars argue that by bringing just transition goals and implementation strategies into energy justice frameworks, the social repercussions of energy transitions could be explored beyond the energy sphere itself.[125]

Finally, the climate justice goal is to ameliorate the unequal distribution of climate change environmental costs and risks on vulnerable communities.[126] Climate justice claims are then closely related to environmental justice, especially among social movements. Indeed, "[c]ontemporary climate justice groups mobilize multiple strands of environmental justice."[127] Just transition frameworks could enrich the analysis by providing opportunities for grassroots organizations to participate in development.[128] For example, "climate justice and litigation can be seen as vehicles through which the just transitions framework can be applied to foster inclusivity and responsiveness of legal and regulatory systems."[129]

Therefore, a broad just transition framework could function as an umbrella concept to strengthen and combine efforts from the environmental, energy, and climate justice fields. This vigorous push toward a just transition enriched by overlapping goals and implementation of these specific sectors could serve as the foundational pillar for a new framework in SAI research and deployment. A just transition framework could "ensure that highly technical efforts to regulate emerging innovations are done in a way that balances the potential for inequity and injustice posed to a wide range of constituencies."[130] Just transition frameworks should not impede innovation, but rather guarantee that innovations are pursued with a wider lens, examining collective benefits, with minimal adverse consequences.[131]

I suggest that a just transition focused on the distributive impacts of environmental policies to face climate change

111. Wang & Lo, *supra* note 65, at 3.
112. *See* Darren McCauley & Raphael Heffron, *Just Transition: Integrating Climate, Energy, and Environmental Justice*, 119 Energy Pol'y 1, 3-5 (2018).
113. *See* IPCC, *supra* note 21, at 75; Baumgartner & Lee, *supra* note 66, at 8.
114. Wilgosh et al., *supra* note 70, at 2; Raphael J. Heffron, *What Is the "Just Transition"?*, *in* Achieving a Just Transition to a Low-Carbon Economy 9, 9 (Springer International Publishing 2021).
115. Wang & Lo, *supra* note 65, at 5; McCauley & Heffron, *supra* note 112, at 1.
116. Robert D. Bullard, *Environmental Justice: It's More Than Waste Facility Siting*, 77 Soc. Sci. Q. 493, 493 (1996).
117. Stephen Williams & Andréanne Doyon, *Justice in Energy Transitions*, 31 Env't Innovation & Societal Transitions 144, 144 (2019); Wang & Lo, *supra* note 65, at 3; Bullard, *supra* note 116, at 493.
118. *E.g.*, Geoff Evans & Liam Phelan, *Transition to a Post-Carbon Society: Linking Environmental Justice and Just Transition Discourses*, 99 Energy Pol'y 329, 329 (2016); Wang & Lo, *supra* note 65, at 4.
119. Wang & Lo, *supra* note 65, at 4.
120. Karen Bickerstaff, *Justice in Energy System Transitions: A Synthesis and Agenda*, *in* The Routledge Handbook of Environmental Justice 388, 388 (Ryan Holifield et al. eds., Routledge 2017); Kacper Szulecki, *Conceptualizing Energy Democracy*, 27 Env't Pol. 21, 26 (2018); Benjamin K. Sovacool & Michael H. Dworkin, *Energy Justice: Conceptual Insights and Practical Applications*, 142 Applied Energy 435, 435 (2015); Darren McCauley, Energy Justice: Re-Balancing the Trilemma of Security, Poverty, and Climate Change 11-13 (2017); Benjamin K. Sovacool, Energy and Ethics: Justice and the Global Energy Challenge 218-20 (2013).
121. Wang & Lo, *supra* note 65, at 5; Williams & Doyon, *supra* note 117, at 148.
122. Williams & Doyon, *supra* note 117, at 148.
123. Stefan Bouzarovski & Neil Simcock, *Spatializing Energy Justice*, 107 Energy Pol'y 640, 641-42 (2017).
124. *E.g.*, Williams & Doyon, *supra* note 117.
125. Healy & Barry, *supra* note 89; Wang & Lo, *supra* note 65, at 5.
126. Jackie Smith & Jacqueline Patterson, *Global Climate Justice Activism: "The New Protagonists" and Their Projects for a Just Transition*, *in* Ecologically Unequal Exchange 245, 245 (R. Scott Frey et al. eds., Springer International Publishing 2019); *see* Paul G. Harris, A Research Agenda for Climate Justice (2019); Harrington, *supra* note 65, at 212.
127. IPCC, *supra* note 21, at 1508.
128. Paul Routledge et al., *States of Just Transition: Realising Climate Justice Through and Against the State*, 88 Geoforum 78, 78 (2018); Harrington, *supra* note 65, at 212.
129. Harrington, *supra* note 65, at 212.
130. *Id.* at 215.
131. *Id.*

causes, effects, and responses must acknowledge a decisive element: the right to a healthy environment. As explored in the following part, the substance of this recently recognized human right could be linked in various ways to a just transition framework. Thus, working toward a just transition with respect for the human right to a healthy environment could move policy and regulations toward a more equitable future, even as private or public efforts research new climate change technologies.

III. The Right to a Clean, Healthy, and Sustainable Environment

In this part, I explore the underpinnings of the right to a healthy environment under a just transition approach. I start by investigating the foundations of the right to a healthy environment, such as its scope and elements. Later, I dig into a theoretical framework to analyze climate change technologies from a just transition and human rights-based approach.

A. A Human Right

In July 2022, UNGA adopted a resolution recognizing the right to a clean, healthy, and sustainable environment.[132] This resolution followed the UNHRC recognition in October 2021,[133] and marked the recognition of the right by the 192 U.N. Member States. This was the result of work historically led by the U.N. that has pushed for a deeper understanding of the relation between human rights and the right to a healthy environment since the 1972 Stockholm Declaration.[134] Besides U.N. proclamations, there are numerous global, local, and domestic frameworks addressing and implementing the right to a healthy environment, bolstering the legal foundation for environmental rights.[135]

For instance, the Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social, and Cultural Rights (San Salvador Protocol) in 1988 already recognized the right to live in a healthy environment.[136] Moreover, before the UNGA recognition, the right to a healthy environment was already legally recognized around the world by 156 countries.[137] Therefore, the key obligations imposed on States to recognize and protect the content of this right are mainly developed in each country's legislation.[138] As the Inter-American Court of Human Rights concluded in 2024, based on all these international and domestic developments "[t]he states have recognized the right to a healthy environment, which entails an obligation of protection that concerns the international community as a whole."[139]

B. Content

Despite the lack of a universal definition on what the right to a healthy environment means,[140] there are minimum substantive and procedural elements.[141] Substantive

132. G.A. Res. 76/300, The Human Right to a Clean, Healthy, and Sustainable Environment (July 28, 2022).

133. UNHRC Res. 48/13, The Human Right to a Clean, Healthy, and Sustainable Environment (Oct. 8, 2021); *see also* Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment, *Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment*, U.N. Doc. A/73/188 (July, 19, 2018) [hereinafter *Human Rights Obligations*]; Elena Cima, *The Right to a Healthy Environment: Reconceptualizing Human Rights in the Face of Climate Change*, 31 RECIEL 38, 43-44 (2022); Marcos Orellana, *Quality Control of the Right to a Healthy Environment*, *in* The Human Right to a Healthy Environment 169, 184-87 (John H. Knox & Ramin Pejan eds., Cambridge Univ. Press 2018) (on the role of the UNHRC in the proclamation of a new human right); Marc Limon, *The Politics of Human Rights, the Environment, and Climate Change at the Human Rights Council*, *in* The Human Right to a Healthy Environment, *supra*, at 189 (explaining the political process and discussion between developing and developed States on recognizing a new universal right to a healthy environment).

134. U.N. Conference on the Human Environment, *Declaration of the United Nations Conference on the Human Environment*, U.N. Doc. A/Conf.48/14/Rev.1, princ. 1 (June 16, 1972); *see* Sueli Giorgetta, *The Right to a Healthy Environment, Human Rights, and Sustainable Development*, 2 Int'l Env't Agreements 171, 175 (2002); Stuart Bell et al., Environmental Law 170 (9th ed. 2017); Rebecca Bratspies, *Do We Need a Human Right to a Healthy Environment*, 13 Santa Clara J. Int'l L. 31, 57 (2015); John H. Knox, *Constructing the Human Right to a Healthy Environment*, 16 Ann. Rev. L. & Soc. Sci. 79, 83 (2020); U.N. Sub-Commission on Prevention of Discrimination and Protection of Minorities, *Draft Declaration of Principles on Human Rights and the Environment* (May 16, 1994).

135. Giorgetta, *supra* note 134, at 175-81; David R. Boyd, The Environmental Rights Revolution: A Global Study of Constitutions, Human Rights, and the Environment 90-91 (2011); *but see id*. at 33-43 (Although it recounts the critiques to the constitutional recognition of the right to a healthy environment, similar arguments could be made against the universal recognition of this right.).

136. Organization of American States, Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social, and Cultural Rights (Protocol of San Salvador) art. 11, Nov. 17, 1988, O.A.S.T.S. No. 69.

137. UNEP et al., What Is the Right to a Healthy Environment? Information Note 8 (2023); David R. Boyd, *The Constitutional Right to a Healthy Environment*, 54 Env't: Sci. & Pol'y for Sustainable Dev. 3, 5 (2012); Boyd, *supra* note 135, at 47; *Human Rights Obligations*, *supra* note 133, ¶ 30.

138. Boyd, *supra* note 135, at 4; Richard P. Hiskes, The Human Right to a Green Future: Environmental Rights and Intergenerational Justice 70 (2009); Tim Hayward, Constitutional Environmental Rights 65 (2004); James R. May & Erin Daly, Global Environmental Constitutionalism 31-36 (2015); *but see* Malgosia Fitzmaurice, *The Right of the Child to a Clean Environment*, 23 S. Ill. U. L.J. 611, 652-53 (1998) (recounting how some countries that had a constitutional recognition of the right to a healthy environment acknowledge its political nature instead of a legal nature); *but see* Richard P. Hiskes, *The Right to a Green Future: Human Rights, Environmentalism, and Intergenerational Justice*, 27 Hum. Rts. Q. 1346, 1364 (2005) ("Relying on the nationalistic concerns of each sovereign state for its own future citizens' welfare [and no one else's] might seem to render the whole appeal of emergent environmental rights too narrowly jingoistic to qualify as universal human rights.").

139. Habitantes de La Oroya v. Peru, Preliminary Objections, Merits, Reparations, and Costs, Judgment, Inter-Am. Ct. H.R. (ser. C) No. 511, ¶ 129 (Nov. 27, 2023) (personal translation).

140. Cima, *supra* note 133, at 44 ("One of the main criticisms directed to the recognition of a human right to a healthy environment has been based on the difficulty to define the exact parameters of this right."); Stephen Turner, A Global Environmental Right 29 (2013); *but see* Sumudu Atapattu, Human Rights Approaches to Climate Change: Challenges and Opportunities 92 (1st ed. 2016) ("[A] distinct right to environment, far from being vague and indeterminate, imposes clear obligations on states to prevent pollution, promote conservation and to secure sustainable development."); Prudence E. Taylor, *From Environmental to Ecological Human Rights: A New Dynamic in International Law*, 10 Geo. Int'l Env't L. Rev. 309, 360-62 (1998).

141. Boyd, *supra* note 135, at 25-27; Turner, *supra* note 140, at 23; Knox, *supra* note 134, at 81; Atapattu, *supra* note 140, at 47; UNEP et al., *supra* note

environmental rights are the ones that "recognize a right to some degree of environmental quality."[142] In the international sphere, this substantive right comprises the right to "a quality that permits the enjoyment of all guaranteed human rights."[143] Thus, substantive rights look to enshrine a level of environmental protection through the right to a healthy environment itself or through other substantive rights such as the right to life.[144]

Besides the recent recognition by UNGA, there has been a limited evolution of substantive environmental rights at the international level.[145] According to the U.N. Environment Programme (UNEP), as proposed by the Special Rapporteur on the Environment, the substantive content of the right to a healthy environment includes "clean air; a safe and stable climate; access to safe water and adequate sanitation; healthy and sustainably produced food; nontoxic environments in which to live, work, study and play; and healthy biodiversity and ecosystems."[146]

Within the substantive content, for the analysis of SAI research and deployment, the right to a safe and stable climate is essential. Certainly, SAI techniques look to ensure a stable climate by releasing substances that might have a significant side effect on the climate itself. As the U.N. Special Rapporteur on Human Rights and the Environment has highlighted, the safe climate element is "informed by commitments made under international environmental treaties, United Nations Framework Convention on Climate Change, wherein States pledged to 'prevent dangerous anthropogenic interference with the climate system,' or in other words to maintain a safe climate."[147]

On the other hand, the procedural side of the right to a healthy environment aims to help in the implementation of substantive rights.[148] Procedural rights originate in the fair governance idea of the Universal Declaration of Human Rights and the International Covenant on Civil and Political Rights.[149] These rights are a sort of "environmental due process,"[150] and comprise "access to information, the right to participate in decision-making, and access to justice and effective remedies, including the secure exercise of these rights free from reprisals and retaliation."[151] These procedural rights have concentrated far more attention than substantive rights, since the latter are highly contested in the international arena.[152]

Among procedural rights, scholars highlight the relevance of decisionmaking participation as a core right.[153] Indeed, the legitimacy of environmental decisions relies on widely informed decisions that encourage appropriate weighting of the consequences.[154] Others highlight the importance of promoting access to timely and reliable information.[155] Behind this array of tools, there is an underlying belief that procedural rights are essential in building "governance structures capable of adopting fair and appropriate environmental policies."[156]

At the international level, the procedural facet of the right to a healthy environment has been included in many instruments.[157] Regarding the analysis of SAI and solar geoengineering, among the key provisions are Article 6(a) of the UNFCCC,[158] Article 12 of the Paris Agreement,[159] Principle 10 of the Rio Declaration of 1992,[160] as well as several paragraphs of the Rio Declaration of 2012, "The Future We Want."[161] In 2021, the Just Transition Declaration signed by more than 30 countries at COP26 of the UNFCCC agreed to "[s]upport and promote social dialogue and stakeholder engagement."[162] In 2023, during COP28 of the UNFCCC, its work program acknowledged the need to develop "[i]nclusive and participatory

137, at 9; *but see* Hurst Hannum, Rescuing Human Rights: A Radically Moderate Approach 50 (2019) (questioning whether it is possible to "develop sufficiently precise and universally applicable norms"); *Report of the Special Rapporteur*, *supra* note 20, at 5:

> [T]he "human right to a healthy environment" is not an empty vessel waiting to be filled; on the contrary, its content has already been clarified, through recognition by human rights authorities that a safe, clean, healthy and sustainable environment is necessary for the full enjoyment of the human rights to life, health, food, water, housing and so forth.

142. May & Daly, *supra* note 138, at 64; *Report of the Special Rapporteur*, *supra* note 20, at 7, 14-15.
143. Dinah Shelton, *Developing Substantive Environmental Rights*, 1 J. Hum. Rts. & Env't 89, 104 (2010).
144. May & Daly, *supra* note 138, at 65; Atapattu, *supra* note 140, at 47; James W. Nickel, *The Human Right to a Safe Environment: Philosophical Perspectives on Its Scope and Justification*, 18 Yale J. Int'l L. 281, 284-85 (1993); Taylor, *supra* note 140, at 338-43; Shelton, *supra* note 143, at 112.
145. Turner, *supra* note 140, at 26; Shelton, *supra* note 143, at 90.
146. UNEP et al., *supra* note 137, at 9; Special Rapporteur on Human Rights and the Environment, *supra* note 13, at 13; Sumudu Atapattu & Andrea Schapper, Human Rights and the Environment: Key Issues 109-28 (2019); Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment, *Report of the Special Rapporteur*, U.N. Doc. A/HRC/31/52, at 16-19 (Feb. 1, 2016) [hereinafter *2016 Report of the Special Rapporteur*]; Habitantes de La Oroya v. Peru, Preliminary Objections, Merits, Reparations, and Costs, Judgment, Inter-Am. Ct. H.R. (ser. C) No. 511, ¶ 118 (Nov. 27, 2023).
147. Special Rapporteur on Human Rights and the Environment, *supra* note 13, at 13.
148. May & Daly, *supra* note 138, at 77, 238-39.
149. *E.g.*, G.A. Res. 217 (111) A, arts. 10, 21, 28, 29(2), Universal Declaration of Human Rights (Dec. 10, 1948); International Covenant on Civil and Political Rights, Dec. 16, 1966, 999 U.N.T.S. 171; Turner, *supra* note 140, at 24.
150. Taylor, *supra* note 140, at 343.
151. UNEP et al., *supra* note 137, at 9; Atapattu & Schapper, *supra* note 146, at 129-53; John H. Knox (Independent Expert on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment), *Report of the Independent Expert*, U.N. Doc. A/HRC/RES/22/43, at 10-12 (Dec. 24, 2012); *2016 Report of the Special Rapporteur*, *supra* note 146, at 13-16; *Report of the Special Rapporteur*, *supra* note 20, at 11-13; G.A. Res. 76/300, *supra* note 132, pmbl.; Habitantes de La Oroya v. Peru, Preliminary Objections, Merits, Reparations, and Costs, Judgment, Inter-Am. Ct. H.R. (ser. C) No. 511, ¶ 118 (Nov. 27, 2023).
152. Shelton, *supra* note 143, at 90-91.
153. *See* Fitzmaurice, *supra* note 138, at 655 ("The most important thing of all for enforcement of collective environmental rights and interests is the widest possible participation in the environmental decision-making process.").
154. Joseph L. Sax, *The Search for Environmental Rights*, 6 Fla. State U. J. Land Use & Env't L. 5, 96-99 (1990); Nickel, *supra* note 144, at 287.
155. May & Daly, *supra* note 138, at 239-43.
156. Bratspies, *supra* note 134, at 54.
157. Knox, *supra* note 151, at 10-12.
158. UNFCCC, May 9, 1992, S. Treaty Doc. No. 102-38, 1771 U.N.T.S. 107.
159. Paris Agreement to the UNFCCC, Dec. 12, 2015, T.I.A.S. No. 16-1104.
160. U.N. Conference on Environment and Development, *Rio Declaration on Environment and Development*, U.N. Doc. A/CONF.151/26/Rev.1(Vol.1) (Aug. 12, 1992) [hereinafter *Rio Declaration*].
161. *E.g.*, U.N. Conference on Sustainable Development, *The Future We Want*, ¶¶ 44, 45, 46, 76, 85, U.N. Doc. A/CONF.216/L.1 (June 19, 2012).
162. Government of the United Kingdom et al., *supra* note 100.

approaches to just transitions that leave no one behind."[163] Together, these provisions emphasize the importance of facilitating access to relevant information and promoting public engagement.[164]

Complementing this analysis, the U.N. Special Rapporteur on Human Rights and the Environment issued a report on 16 framework principles guiding States on how to implement the right to a healthy environment through a human rights framework.[165] It is remarkable how the principles flesh out many of the associated obligations to implement the procedural and also substantive content of the right to a healthy environment.[166] These principles also explore the relation of other human rights with the right to a healthy environment, such as the rights to freedom of expression, association, and peaceful assembly, or the duty to conduct a prior EIA.[167]

Moreover, a case decided in early 2024 by the Inter-American Court of Human Rights added more layers to this robust framework. Residents from La Oroya, one of the most contaminated cities in the world, brought a case against the Peruvian government for infringing their right to a healthy environment, to health, to life, and to physical integrity, among others.[168] The residents argued that the cause of such violation was the inaction of the government on regulating the pollution emitted by La Oroya Metallurgical Complex, a polymetallic smelting and refining plant.[169] The court ruled that Peru was responsible for the physical and mental harm caused by the pollution emanating from the plant, affecting 80 people.[170]

Regarding the right to a healthy environment, the court dedicates almost 10 pages to the content of this right only.[171] First, the court emphasizes the legal recognition of the right to a healthy environment by the Organization of American States, the San Salvador Protocol, the domestic constitutional recognition in America by more than 16 countries—including Peru, and the recent recognition by the UNHRC and UNGA.[172]

Then, the court refers to another dimension of the right to a healthy environment, stating that this right protects environmental components, such as forests or rivers, as legal interests in and of themselves, independently from the risks these activities might pose to humans.[173] Thus, "states are obligated to protect nature not only for its usefulness or effects regarding humans, but for its importance to other living organisms with whom we share the planet."[174] In this regard, if the plant contaminated air and water, then it contaminated aquatic ecosystems, flora and fauna, and soil, which could have affected the basic content of rights such as the life and health of the people around it.[175]

In summary, the substantive content of the right to a healthy environment is essential in recognizing the vital link between human well-being and environmental protection. It asserts access to clean air, water, and unpolluted surroundings as a fundamental human right, encompassing biodiversity preservation and climate change policies such as a stable climate. On the other hand, the procedural dimension emphasizes the importance of transparency, accountability, and inclusivity in environmental governance, empowering individuals to engage actively in environmental issues such as solar engineering research and deployment. As developed throughout this Article, in the face of escalating environmental challenges, such as climate change, the right to a healthy environment serves as a guiding principle for policymaking and collective action to promote sustainable development and protect future generations' health and dignity.

C. *Implications of Its Recognition*

Having analyzed the recent developments on the right to a healthy environment, here I comment on the strategic advantages of such recognition and its relationship with a just transition framework and SAI. A burning question is: What are the main implications of recognizing the right to a healthy environment as a human right?[176] There are recent analyses on the possible outcomes of this recognition.[177] Some commentators focus broadly on how the right to a healthy environment can influence the international human rights system as whole,[178] while others focus on the consequences within the environmental sphere.[179]

163. COP28 UNFCCC, *supra* note 101, §2, para. 6.
164. *E.g.*, Railla Veronica D. Puno, *A Rights-Based Approach to Governance of Climate Geoengineering*, 50 ELR 10744, 10751 (Sept. 2020).
165. *Report of the Special Rapporteur*, *supra* note 20.
166. *E.g.*, *id*. at 14-15.
167. *Id.* at 10-12.
168. Habitantes de La Oroya v. Peru, Preliminary Objections, Merits, Reparations, and Costs, Judgment, Inter-Am. Ct. H.R. (ser. C) No. 511, ¶ 1 (Nov. 27, 2023).
169. *Id.*
170. *Id.* ¶¶ 393.3-.10.
171. *Id.* ¶¶ 115-129.
172. *Id.* ¶¶ 115-117.
173. *Id.* ¶ 118 (personal translation).
174. *Id.* (personal translation).
175. *Id.* ¶ 119.
176. Burns H. Weston & David Bollier, *Toward a Recalibrated Human Right to a Clean and Healthy Environment: Making the Conceptual Transition*, 4 J. Hum. Rts. & Env't 116, 126-28 (2013) (analyzing the consequences or recognizing the right to a healthy environment as a human right and legal and political empowerments); Bratspies, *supra* note 134, at 36, 38, 39-43 (recounting some of the pressing questions on relying on human rights to achieve environmental goals); *see also* Boyd, *supra* note 135, at 5-12 (addressing the advantages of a constitutional recognition of the right to live in a healthy environment through the experience in 92 countries); Orellana, *supra* note 133, at 181-82.
177. *See, e.g.*, Knox, *supra* note 134, at 89-91; UNEP et al., *supra* note 137, at 10; John H. Knox & Ramin Pejan, *Introduction*, *in* The Human Right to a Healthy Environment, *supra* note 133, at 1 (acknowledging that the relation between human rights and a healthy environment has already been recognized at "every level of the world's legal systems, from domestic courts to multilateral treaties"); Sumudu Atapattu, *The Right to a Healthy Environment and Climate Change*, *in* The Human Right to a Healthy Environment, *supra* note 133, at 252, 266 ("The link between human rights and the environment is no longer disputed and human rights institutions have endorsed this link.").
178. *E.g.*, Cima, *supra* note 133 (suggesting that the recognition of the right to a healthy environment as a human right could trigger a paradigm shift within the human rights system, incorporating the concepts of prevention, common concern of humankind, and intergenerational equity); Roda Mushkat, *Contextualizing Environmental Human Rights: A Relativist Perspective*, 26 Pace Env't L. Rev. 119, 133-40 (2009).
179. *E.g.*, Nickel, *supra* note 144, at 283; Taylor, *supra* note 140, at 346-47.

A general consequence of recognizing the right to a healthy environment as a human right is that the Parties to such declaration are required to enact legislation "to respect, protect and fulfil the right to a clean, healthy and sustainable environment."[180] Therefore, States must abstain from endangering the exercise of such a right,[181] as well as taking "affirmative measures to deter, prevent, investigate, and punish violations of human rights by private actors."[182] The obligation to fulfill this right could be materialized through its legal recognition or by advancing further policies to facilitate its enjoyment.[183]

Certainly, the recognition by UNGA increases the awareness of implementing minimal environmental standards of protection.[184] Given the broader global scope of environmental problems, the active collaboration of all countries is essential to achieve meaningful results, especially regarding climate engineering technologies.[185] Therefore, the UNGA recognition reinforces legal frameworks that promote environmental preservation.[186]

However, there are opposing views on whether human rights law can truly shape or influence the domestic content of each country.[187] Despite the fact that recognition by UNGA was supported by 163 States voting in favor and eight abstaining,[188] the right to a healthy environment still does not constitute clear customary international law, which, as in all international law issues, makes it difficult to enforce among the few countries who still do not recognize it in their domestic legal systems.[189] Despite the concerns about the power of international forums for addressing environmental rights violations,[190] the underlying principles of human rights law could incite the advancement of domestic environmental legislation.[191] Moreover, the international perspective of UNGA recognition could help "fill gaps left by constitutional rights."[192]

Consequently, the recognition as a human right can also mark the beginning for discussions at the domestic level in countries where the right to a healthy environment has not been legally recognized yet.[193] Indeed, recent studies have proven that human rights law is more likely to be influential on States whose democratic legal frameworks do not address the issue, and where the recognition can be used to press for legal changes.[194]

More importantly, recognition of the right to a healthy environment plays a key role in advancing the environmental and climate justice agenda. Its recognition entitles individuals in some jurisdictions, by vesting them with a legal interest to seek enforcement, redress, and remedy.[195] Certainly in recognizing this right, local communities and citizens are empowered to act in cases of environmental degradation.[196] Particularly, it provides victims with the opportunity to seek a remedy against individuals infringing on their rights.[197] Citizens that are harmed by the impacts of SAI research and deployment could make claims based on human rights violations.[198] Thus, with the recognition of a human right to a healthy environment, States are more likely to be held accountable at the international[199] or domestic level.[200]

180. David R. Boyd (Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy, and Sustainable Environment), *The Human Right to a Clean, Healthy, and Sustainable Environment: A Catalyst for Accelerated Action to Achieve the Sustainable Development Goals*, U.N. Doc. A/77/284, at 7 (Aug. 10, 2022); *The Role of Human Rights in Implementing CDR Geoengineering Options in South Africa*, *in* Climate Geoengineering: Science, Law, and Governance, *supra* note 20, at 150.
181. *2016 Report of the Special Rapporteur*, *supra* note 146, at 16; Burns, *supra* note 5, at 19; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 125-26.
182. Burns, *supra* note 5, at 19.
183. *Right to a Healthy Environment: Good Practices*, *supra* note 19, at 4; Burns, *supra* note 5, at 19.
184. Bratspies, *supra* note 134, at 36; Taylor, *supra* note 140, at 357-58; *Report of the Special Rapporteur*, *supra* note 20, at 5.
185. James T. McClymonds, *The Human Right to a Healthy Environment: An International Legal Perspective*, 37 N.Y.L. Sch. L. Rev. 583, 592 (1992).
186. Boyd, *supra* note 135, at 6; *but see* Günther Handl, *Human Rights and Protection of the Environment: A Mildly "Revisionist" View*, *in* Human Rights, Sustainable Development, and Environment 117 (Antônio Augusto Cançado Trindade ed., Instituto Interamericano de Derechos Humanos 1992) (against the advantages of a generic human right to the environment); Sumudu Atapattu, *The Right to a Healthy Life or the Right to Die Polluted: The Emergence of a Human Right to a Healthy Environment Under International Law*, 16 Tul. Env't L.J. 65, 125-26 (2002) (arguing that a right to sustainable development would be more effective than a limited right to a healthy environment).
187. Knox, *supra* note 134, at 88 (summarizing the discussion, and concluding that positive effects of international treaties recognizing human rights are more likely to impact States where these can be used to press for transformational changes); Hari M. Osofsky, *Learning From Environmental Justice: A New Model for International Environmental Rights*, 24 Stan. Env't L.J. 71, 230 (2005).
188. U.N. GAOR, 76th sess., 97th plen. mtg., at 10-11, U.N. Doc. A/76/PV.97 (July 28, 2022). The abstentions were Belarus, Cambodia, China, Ethiopia, Iran, Kyrgyzstan, the Russian Federation, and the Syrian Arab Republic.
189. *But see* Vanessa James, Recognition of the Human Right to a Healthy Environment as Customary International Law (2023) (Ph.D. thesis, Victoria University of Wellington) (arguing that the right to a healthy environment already constitutes customary international law, especially through the U.N. Sustainable Development Goals (SDGs)).
190. Osofsky, *supra* note 187, at 248-49.
191. Knox, *supra* note 134, at 90; *see also* Nickel, *supra* note 144, at 292-93 (analyzing whether the moral and legal burden of ensuring the right to a healthy environment can be legitimately imposed, which would substantiate the effectiveness of the right itself).
192. Knox, *supra* note 134, at 90; Stephen Gardbaum, *Human Rights as International Constitutional Rights*, 19 Eur. J. Int'l L. 749, 764-65 (2008).
193. UNEP et al., *supra* note 137, at 10.
194. Knox, *supra* note 134, at 88; Kevin L. Cope & Cosette D. Creamer, *Disaggregating the Human Rights Treaty Regime*, 56 Va. J. Int'l L. 459, 474-79 (2016); César Rodríguez-Garavito, *A Human Right to a Healthy Environment? Moral, Legal, and Empirical Considerations*, *in* The Human Right to a Healthy Environment, *supra* note 133, at 155, 165-66.
195. Taylor, *supra* note 140, at 358-59; UNEP, Environmental Rule of Law: Tracking Progress and Charting Future Directions 107-08 (2023).
196. McClymonds, *supra* note 185, at 592-93 (analyzing in the early 1990s why protecting environmental values from a human rights perspective would empower individuals before nation-States under international law); Handl, *supra* note 186, at 114-15; Rodríguez-Garavito, *supra* note 194, at 163-65; UNEP, *supra* note 195, at 107-10; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 127-28.
197. Atapattu, *supra* note 140, at 49-50.
198. *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 117.
199. Louis J. Kotzé, *In Search of a Right to a Healthy Environment in International Law: Jus Cogens Norms*, *in* The Human Right to a Healthy Environment, *supra* note 133, at 136, 143.
200. Shelton, *supra* note 143, at 107 ("Enforcement of environmental rights involves courts in not only determining the mandated environmental quality,

Finally, as discussed below, if we conclude that SAI technologies are beyond the scope of existing multilateral environmental agreements (MEAs), such as the UNFCCC or the Vienna Convention for the Protection of the Ozone Layer (Vienna Convention), the human right to a healthy environment could still be crucial in informing minimum obligations to govern SAI research and deployment. A prime example is the use of humanitarian reasons by geoengineering developers in the climate change intervention discourse. These developers could argue that geoengineering is necessary to avoid the worst humanitarian crises such as massive global migrations. In this scenario, "humanitarian stakeholders will need a framework to prioritize positions and actions that address causes and consequences."[201] For them, the right to a healthy environment could provide a robust option from which to address SAI research and deployment.

IV. Between a Just Transition and a Healthy Environment

The just transition concept emerged from a narrow labor perspective and is expanding into wider horizons. Throughout this expansion, there is a growing consensus in the U.N. that the transition must adhere to a human rights approach, including the right to a healthy environment.[202] For instance, this would entail addressing the Sustainable Development Goals (SDGs),[203] as well as adhering to Paris Agreement directives,[204] among other MEAs. For instance, the Paris Agreement acknowledges that "[p]arties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights."[205]

However, there has been no further analysis of the relationship between the newly recognized right and a just transition. Some attribute the scarcity of literature on rights-based approaches and climate change to the absence of an operational framework to lead relevant actors.[206] Thus, this part explores how we can connect a just transition, the right to a healthy environment, and SAI endeavors.

A just transition framework is essential for alleviating the environmental and socioeconomic impacts of government policies to decarbonize placed on local communities.[207] Indeed, the focus of this framework is that both State and sub-State actors adhere to the text and underlying principles of international and national legal obligations, guaranteeing the protection of communities' rights.[208]

Complementing this, "[h]uman rights and environmental protection are interdependent."[209] Recognition of the human right to a healthy environment imposes new duties within global human rights, strengthening the case for a just transition framework. This development suggests that the entire system of international human rights could play a crucial role in advocating for and ensuring the realization of a just transition.

Certainly, future deployment of geoengineering projects at a large scale around the world raises many issues within the international environmental law community.[210] Especially since these "new and emerging technologies intended for climate protection have not been extensively examined from the human rights viewpoint."[211] Meanwhile, policies to face the climate catastrophe "are in turn producing even more serious human rights concerns, especially in developing countries."[212] Thus, we must ensure that such measures do "not exacerbate existing vulnerabilities and . . . be taken in consultation with the affected stakeholders."[213]

In other words, to minimize the unequal socioeconomic impacts of climate change policies on vulnerable communities, we must ensure observance of the human right to a healthy environment.[214] Indeed, the right to a healthy environment, combined with environmental, energy, and climate justice claims, would call for correcting most of the unequal impact distribution of climate change. At the same time, by using a just transition framework, the impacts arising from unjust environmental transitions can be more easily identified.[215]

A. *Mainstreaming Human Rights*

A first connection between human rights and just transition frameworks and SAI activities is made by mainstreaming human rights into the regulation of this technology.[216] Mainstreaming entails a key principle: that human rights are essential for all facets of human development.[217] Basically, this holistic view implies incorporating human rights in all public policies.[218]

Thus, by mainstreaming human rights, we could build "a practical framework through which human rights principles and standards can be integrated and reflected in decision-making processes to ensure coherence, harmo-

but also in assessing whether or not the government has taken the requisite actions to achieve that quality.").

201. Svoboda et al., *supra* note 13, at 14; *see* Prantl et al., *supra* note 6, at 39-40.
202. Working Group on the Issue of Human Rights and Transnational Corporations and Other Business Enterprises, *Extractive Sector, Just Transition, and Human Rights*, U.N. Doc. A/78/155, at 4 (July 11, 2023); Special Rapporteur on Human Rights and the Environment, *supra* note 13, at 22.
203. Boyd, *supra* note 180, at 5-9.
204. Working Group on the Issue of Human Rights and Transnational Corporations and Other Business Enterprises, *supra* note 202, at 4.
205. Paris Agreement to the UNFCCC pmbl., Dec. 12, 2015, T.I.A.S. No. 16-1104; Puno, *supra* note 164, at 10750. *See supra* Section I.B.
206. Thomas Greiber et al., International Union for Conservation of Nature, Conservation With Justice: A Rights-Based Approach 3 (2009); Olawuyi, *supra* note 18, at 21.
207. Harrington, *supra* note 65, at 210.
208. *Id.*
209. *Report of the Special Rapporteur*, *supra* note 20, at 7.
210. Reynolds, *supra* note 10, at 71.
211. UNHRC, *supra* note 14, at 2.
212. Olawuyi, *supra* note 18, at 383.
213. Atapattu, *supra* note 140, at 127.
214. Johansson, *supra* note 66, at 230; Bodansky et al., *supra* note 20, at 299.
215. Harrington, *supra* note 65, at 212.
216. G.A. Res. 52/12, Renewing the United Nations: A Programme for Reform, ¶¶ 78-79 (Nov. 14, 1997); *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 118.
217. Olawuyi, *supra* note 18, at 154.
218. *Id.* at 149; Christopher McCrudden, *Mainstreaming Human Rights*, *in* Human Rights in the Community: Rights as Agents for Change 9 (Colin Harvey ed., Hart Publishing 1st ed. 2004).

nization, and effectiveness."[219] In particular, by incorporating human rights at earlier decisionmaking stages we could prevent human rights violations, reducing collisions between human rights and SAI projects.[220] This approach can also be nuanced by understanding a human rights framework as a source of cross-cutting principles, which should inform the content and application of the right to a healthy environment.[221]

Thus, we need to mainstream the human right to a healthy environment into the just transition framework. In fact, a legal framework that addresses solar geoengineering endeavors along with the human right to a healthy environment could lead to more effective regulation in the long term.[222] The specific approach to mainstream human rights into climate change governing structures is a highly contested question.[223] Indeed, "scholars have yet to agree on the appropriate legal and institutional framework for achieving the linkages and legal partnerships between human rights and climate change under international law."[224]

I argue that such discussion on how to link human rights and climate change could be resolved with the recognition in 2022 by UNGA of a human right to a healthy environment.[225] This recognition could be the missing link to build a robust normative framework and make the case for including a human rights perspective into climate change governance. Therefore, if the path is clear, we should incorporate a human rights lens through a combination of both substantive and procedural aspects of the right to a healthy environment and just transition framework.

B. A Human Rights-Based Approach

1. Preliminary Considerations

Among the many tensions between SAI deployment and local communities,[226] a critical question is the relation between the deployment of these technologies and human rights. As in most of the issues presented in this Article, research is scarce.[227] Still, there is increasing attention to the perils of developing SAI, especially regarding how its side effects could "endanger the respective human rights to the elementary preconditions of freedom, such as life, health, and subsistence."[228]

In response, authors explore the possible clashes of climate geoengineering techniques with human rights.[229] Usually, they do so by enumerating specific human rights and their potential endangerment through the research and deployment of these technologies.[230] I approach this issue from the perspective that human rights are essential for delivering a normative framework that facilitates evaluating SAI endeavors.[231] Certainly, human rights could work as a normative anchor for the geoengineering discourse.[232] As the UNHRC has noted, the collaboration of human rights and communities impacted by climate change is essential "to build capacity to deliver responses to climate change that respect and promote human rights."[233]

2. Why a Human Rights-Based Approach?

"The application of a rights-based approach puts a human face on the triple environmental crisis."[234] But what does it mean to adopt a human rights-based approach? It is one of the ways in which human rights can be mainstreamed into public policies, and it means adopting "a conceptual framework for the process of human development that is normatively based on international human rights standards and operationally directed to promoting and protecting human rights."[235]

The lens of the right to a healthy environment means integrating "its substantive and procedural elements . . . as well as human rights principles such as inclusivity and universality, equality and non-discrimination, and accountability."[236] This is essential, since equitable, inclusive, and participatory human rights-based approaches are more effective in ensuring sustainable results to fight climate change issues.[237]

219. Olawuyi, *supra* note 18, at 149.
220. *Id.* at 139; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 115-16.
221. *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 118.
222. Svoboda et al., *supra* note 13, at 12.
223. Olawuyi, *supra* note 18, at 197.
224. *Id.* at 197, 198-229.
225. *See supra* Section II.A.
226. *See* Section III.A.
227. UNHRC, *supra* note 14, at 2; Flegal et al., *supra* note 3, at 409, 412; Reynolds, *supra* note 10, at 106; *The Role of Human Rights in Implementing CDR Geoengineering Options in South Africa*, *supra* note 180, at 147 ("[T]he nexus between human rights and climate change interventions, that is, measures in response to climate change, in particular climate engineering, is only a subject of recent scholarly effort.").
228. Jutta Wieding et al., *Human Rights and Precautionary Principle: Limits to Geoengineering, SRM, and IPCC Scenarios*, 12 Sustainability 8858 (2020).
229. Reynolds, *supra* note 10, at 106 (recounting the existing scholarship and claims on the relation between human rights and geoengineering).
230. *E.g.*, Burns, *supra* note 5, at 20-22; Reynolds, *supra* note 10, at 113; UNHRC, *supra* note 14, at 12-14; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 123-25.
231. Reynolds, *supra* note 10, at 106.
232. Rider W. Foley et al., *Towards the Anticipatory Governance of Geoengineering*, *in* Geoengineering Our Climate? 220 (Jason J. Blackstock & Sean Low, Routledge 1st ed. 2018).
233. UNHRC Res. 47/24, Human Rights and Climate Change, at 5 (July 26, 2021); *The Role of Human Rights in Implementing CDR Geoengineering Options in South Africa*, *supra* note 180, at 148-49.
234. Boyd, *supra* note 180, at 10; *see* Bodansky et al., *supra* note 20, at 300.
235. Office of the United Nations High Commissioner for Human Rights (OHCHR), Frequently Asked Questions on a Human Rights-Based Approach to Development Cooperation 15 (2006); U.N. Development Group, The Human Rights Based Approach to Development Cooperation: Towards a Common Understanding Among UN Agencies 1-3 (2003); Margaux J. Hall, *Advancing Climate Justice and the Right to Health Through Procedural Rights*, 16 Health & Hum. Rts. J. 8, 15 (2014); Olawuyi, *supra* note 21, at 110 (recounting recent literature delving into the human rights-based approach).
236. UNEP et al., *supra* note 137, at 12; Special Rapporteur on Toxics and Human Rights, *supra* note 15, at 17; Boyd, *supra* note 180, at 10.
237. IPCC, *Summary for Policymakers*, *in* Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to

International human rights law is critical in shaping "a useful framework to evaluate mitigation and adaptation measures adopted by states."[238] A human rights-based approach "could provide a normative framework and language of accountability for climate interventions,"[239] such as SAI. Thus, applying a human rights-based approach to SAI through the lens of the right to a healthy environment would encompass goals of more inclusive and equitable policies.[240] Many of the questions arising from SAI research and deployment could be analyzed through this human rights-based approach[241]: for instance, whether SAI's unintended side effects are compatible with human rights, or whether it is possible to deploy SAI in a manner that is compatible with human rights and a just transition.

So, how would we incorporate this human rights-based approach to disputes over SAI research and deployment? Basically, a human rights-based approach entails identifying rights-holders along with their entitlements on one side, and duty-bearers with their particular obligations on the other, with the aim of improving the fulfillment of their respective obligations.[242] A few authors have already developed novel proposals to include a human rights-based approach, such as applying an HRIA to geoengineering techniques.[243] This procedure can also be conducted in parallel to an EIA.[244]

Besides EIAs, an HRIA could be an effective procedure to identify the impacts of SAI techniques on human rights and affected communities.[245] Indeed, HRIAs are already considered as a mechanism for business enterprises to identify the potential human rights impacts of their activities.[246] Recent literature suggests that such procedures could improve the assessment of the "consistency of policies, legislation, projects and programs with human rights."[247]

Generally, an HRIA is conducted in eight stages, similarly to an EIA.[248] As Wil Burns suggests, "an HRIA process might lead the world community to opt for a strictly limited application of geoengineering options concordant with protection of human rights."[249] Therefore, an HRIA could be an effective vehicle to identify risks and often means working toward the right to a healthy environment and a just transition. Indeed, its procedure could clarify whether specific SAI endeavors are consistent with this framework.

C. *SAI Deployment Under the Right to a Healthy Environment*

SAI could impact the enjoyment of many human rights.[250] Still, uncertainty surrounds the social and environmental impacts of SAI research and deployment, which makes it hard to adopt a clear position to forbid or allow its advancement.[251] Besides the benefits of SAI, such as reducing global temperatures and climate change impacts,[252] there are many unintended side effects and risks.[253] This section analyzes how the right to a healthy environment could shape the planning, implementation, and assessment of SAI technologies by drawing new connections under its potential benefits and pitfalls.

Currently, there are many scientific and international efforts to promote research about the environmental outcomes of these new technologies.[254] For instance, the most advanced MEA, the Montreal Protocol, calls for research about SAI and its potential consequences for the stratosphere and ozone layer.[255] Without such research results, it will be unclear if SAI deployment endangers the right to a healthy environment and just transition goals.[256]

SAI must be analyzed from the lenses of the right to a healthy environment and a just transition to avoid the unequal distribution of its socioeconomic effects on vulnerable groups. Indeed, human rights agreements impose many obligations on States when developing climate change policies.[257] More specifically, the human right to a healthy environment "adopts a framework of equity, jus-

the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 3, 29 (Hans-Otto Pörtner et al., Cambridge Univ. Press 2022); IPCC, *supra* note 2, at 31; OHCHR, *supra* note 235, at 16.

238. Atapattu, *supra* note 140, at 293-94.
239. Svoboda et al., *supra* note 13, at 2; Bodansky et al., *supra* note 20, at 299-300.
240. *E.g.*, Puno, *supra* note 164, at 10751.
241. Reynolds, *supra* note 10, at 113 (suggesting that a human rights-based approach could be operationalized by using an HRIA, which "could help ensure that human rights are protected . . . through solar geoengineering").
242. OHCHR, *supra* note 235, at 15; Svoboda et al., *supra* note 13, at 8.
243. Burns, *supra* note 5, at 23-27; Atapattu, *supra* note 140, at 294; Greiber et al., *supra* note 206; Puno, *supra* note 164, at 10752-54; Svoboda et al., *supra* note 13, at 8-9; UNHRC, *supra* note 14, at 11.
244. Burns, *supra* note 5, at 23-24.
245. Reynolds, *supra* note 10, at 113; Burns, *supra* note 5, at 23; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 122.
246. Désirée Abrahams & Yann Wyss, International Business Leaders Forum & International Finance Corporation, Guide to Human Rights Impact Assessment and Management (HRIAM) 12-13 (2010); OHCHR, Guiding Principles on Business and Human Rights: Implementing the United Nations "Protect, Respect, and Remedy" Framework 19-22 (2011).
247. Burns, *supra* note 5, at 23.
248. World Bank & Nordic Trust Fund, Human Rights Impact Assessments: A Review of the Literature, Differences With Other Forms of Assessments, and Relevance for Development 22-30 (2013) (These stages range from identifying the context of the assessment; narrowing the activities to assess (screening); drafting the terms of reference for the assessment and identifying the baseline and options (scoping); gathering evidence; submitting the process to public consultation; analyzing the information; developing conclusions and recommendations; and monitoring and evaluation.).
249. Burns, *supra* note 5, at 27.
250. Special Rapporteur on Toxics and Human Rights, *supra* note 15, at 15; UNHRC, *supra* note 14, at 12-14.
251. *E.g.*, Reynolds, *supra* note 10, at 101; National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 105; Joshua B. Horton & Barbara Koremenos, *Steering and Influence in Transnational Climate Governance: Nonstate Engagement in Solar Geoengineering Research*, 20 Glob. Env't Pol. 93, 99 (2020).
252. *See* Kreuter, *supra* note 25, at 224 (current literature analyzing the benefits of SAI engage from a cost and benefit analysis perspective). *Accord A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 112.
253. WMO, *supra* note 5, at 361. *See also supra* Section I.B.
254. Andersen & Gonzalez, *supra* note 7, at 189.
255. *E.g.*, Montreal Protocol Decision XXXV/4: Stratospheric Aerosol Injection and Protection of the Ozone Layer (2023).
256. John Virgoe, *International Governance of a Possible Geoengineering Intervention to Combat Climate Change*, 95 Climatic Change 103, 117 (2009).
257. Atapattu, *supra* note 140, at 126; *The Role of Human Rights in Implementing CDR Geoengineering Options in South Africa*, *supra* note 180, at 146-47.

tice, and fairness."[258] With this focus on the role of the right to a healthy environment in achieving a just transition, I aim to contribute to the discussion on "balancing the competing human rights implications of climate engineering policies on the one hand, and climate change burdens in the absence of such policies on the other."[259]

Human rights obligations, such as the substantive and procedural content of the right to a healthy environment, must be incorporated in the climate governance architecture.[260] These obligations would fill gaps on human rights risks induced by climate policies and new technologies.[261] In particular, after recognition by UNGA in 2022, the human right to a healthy environment must shape the international climate governance architecture, including SAI regulations. States must observe such human rights framework while developing appropriate responses to climate change.[262]

Certainly, the relationship between SAI and the human right to a healthy environment underscores the need for comprehensive consideration of both substantive goals and procedural rights. By addressing potential health risks, safeguarding environmental integrity, promoting public participation, and upholding minimum environmental quality standards, policymakers are more likely to ensure that decisions regarding SAI align with the principles and objectives of the right to a healthy environment.

The UNHRC is spearheading this research, especially through a 2023 report on the "[i]mpact of new technologies intended for climate protection on the enjoyment of human rights."[263] In this exhaustive piece, the committee points out that "[t]he magnitude of the potential negative socioeconomic and human rights impacts is currently incommensurable with any hypothetical benefits."[264] In particular, the authors identify potential impacts of SRM testing and deployment on the right to life, the right to a healthy environment, the right to information and public participation, the right to an adequate standard of living, the right to food and water, and the right to access to justice and legal remedies.[265] The authors conclude that the deployment of SRM technologies would be contrary to human rights and environmental frameworks.[266] However, this analysis is shallow, especially regarding the right to a healthy environment, since it does not dedicate more than one paragraph to substantiate this conclusion.

Therefore, again the moral and ethical questions emerge. The UNHRC Advisory Committee serves as an example among other authors pushing to stop any further development of SAI and other geoengineering technologies.[267] Should we forbid any future experimentation and deployment of SAI because of the potential unintended environmental impacts? I think that the collision between the right to a healthy environment and a just transition with SAI development could possibly be resolved through the use of international law tools to address these concerns.

1. Substantive Content

This subsection delves into how to incorporate a human rights-based and just transition framework into SAI. Before that, I address specific implications between the right to a healthy environment's substantive facet and SAI endeavors. As detailed above,[268] the substantive content of the right to a healthy environment alludes to a specific degree of environmental quality that permits the exercise of all the other human rights.[269] This environmental quality can be set for many components, such as ensuring nontoxic environments, safe water, healthy food, and healthy biodiversity and ecosystems.[270] Indeed, the substantive aspect of the right to a healthy environment emphasizes the need to protect individuals from environmental harm, including risks posed by novel technologies.[271] SAI can potentially impact all these substantive variables.

However, current analyses are still incipient.[272] For one thing, there are more potential benefits of SAI deployment than the global reduction of surface temperatures.[273] These benefits could contribute to advance enjoyment of the right to a healthy environment from a substantive perspective.

For instance, there are projections of a reduction in extreme rainfall events and its associated flood risks.[274] Relatedly, there could be a decrease in the frequency of extreme storms in the North Atlantic and heat waves in

258. Atapattu, *supra* note 140, at 126; IPCC, *Summary for Policymakers*, *in* Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 1, 5 (Ottmar Edenhofer et al. eds., Cambridge Univ. Press 2014) ("Issues of equity, justice, and fairness arise with respect to mitigation and adaptation. . . . The evidence suggests that outcomes seen as equitable can lead to more effective cooperation.").
259. Svoboda et al., *supra* note 13, at 2.
260. Olawuyi, *supra* note 18, at 138. *See supra* Part III.
261. Olawuyi, *supra* note 18, at 139.
262. *E.g.*, Atapattu, *supra* note 140, at 136.
263. UNHRC, *supra* note 14, at 2.
264. *Id.* at 12.
265. *Id.* at 12-14.
266. *Id.* at 15, 17.
267. *E.g.*, Aarti Gupta et al., *Towards a Non-Use Regime on Solar Geoengineering: Lessons From International Law and Governance*, 13 Transnat'l Env't L. 368 (2024).
268. *See supra* Section III.B.
269. May & Daly, *supra* note 138, at 64; Shelton, *supra* note 143, at 104.
270. UNEP et al., *supra* note 137, at 9; Special Rapporteur on Human Rights and the Environment, *supra* note 13, at 13; Atapattu & Schapper, *supra* note 146, at 109-28; *2016 Report of the Special Rapporteur*, *supra* note 146, at 16-19.
271. *Report of the Special Rapporteur*, *supra* note 20, at 7-8.
272. *E.g.*, UNHRC, *supra* note 14, at 13; National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 105-06.
273. WMO, *supra* note 5, at 361; *Solar Radiation Management Involves Both Risks and Benefits*, *in* Geoengineering: Counteracting Climate Change 56 (Rita Santos ed., Greenhaven Publishing 1st ed. 2019).
274. Charles L. Curry et al., *A Multimodel Examination of Climate Extremes in an Idealized Geoengineering Experiment*, 119 JGR Atmospheres 3900 (2014); Mansi Bhowmick et al., *Response of the Indian Summer Monsoon to Global Warming, Solar Geoengineering, and Its Termination*, 11 Sci. Reps. 9791 (2021); Duoying Ji et al., *Extreme Temperature and Precipitation Response to Solar Dimming and Stratospheric Aerosol Geoengineering*, 18 Atmospheric Chemistry & Physics 10133 (2018); Liren Wei et al., *Global Streamflow and Flood Response to Stratospheric Aerosol Geoengineering*, 18 Atmospheric Chemistry & Physics 16033 (2018); Huynh & McNeill, *supra* note 7, at 129-30.

Europe.[275] These environmental impacts could help materialize the right to a stable climate, since fluctuations would be constrained to regular events without mega-catastrophes. Further, there could also be a recovery of sea and land ice areas,[276] and an increase in ocean net productivity.[277] These effects could contribute to healthy biodiversity and ecosystems,[278] as well as ensuring healthy food and safer water.[279]

The risks, however, are also many; SAI could potentially cause environmental harms.[280] Some of its side effects are weakening the global hydrological cycle, which in turn would reduce rainfall and its precipitation patterns.[281] SAI could also alter regional climates by forcing a poleward shift of the storm tracks.[282] Even more, it could also increase acid rain, which would be most notable on pristine areas at high latitudes.[283]

There could also be an increase in surface ozone, "due to the increase in stratospheric ozone from both the increasing GHGs, reductions in sunlight, and reductions in stratospheric water vapor."[284] This, in turn, would increase levels of surface ultraviolet radiation, especially in polar regions.[285] Therefore, the release of aerosols into the atmosphere could have far-reaching ecological implications, affecting ecosystems, biodiversity, and the integrity of natural processes.

These environmental impacts would endanger the right to a stable climate, to clean air, to a healthy ecosystem and biodiversity, to safe drinking water, and to nontoxic environments to live in. Although each domestic, transnational, and regional legal framework could set the specific standards, SAI research and deployment could potentially impact each of these substantive components. Indeed, these environmental risks could have jurisdictional effects by testing transboundary liability regimes and States' duty to refrain from causing environmental harm outside their own territory.[286] Thus, the substantive right to a healthy environment highlights the importance of assessing and mitigating potential harms associated with SAI to uphold environmental integrity.

2. Procedural Content

The procedural facet of the right to a healthy environment encompasses the mechanisms and processes through which individuals and communities can effectively claim, protect, and realize this fundamental right.[287] It involves ensuring access to information, participation in decision-making processes, and access to justice in environmental matters.[288] In this regard, the procedural side of the right to a healthy environment is more developed than the substantive, since it appeals to preexisting dispositions from the Universal Declaration of Human Rights and other MEAs such as the Aarhus Convention or the Escazú Agreement.[289]

SAI research and deployment could endanger the procedural aspect of the right to a healthy environment in various ways. Consequently, States must ensure that communities potentially impacted by a proposed SAI project have access to relevant information, can participate through specific public engagement mechanisms, and have means to redress transgressions to their rights.[290] For instance, in a particular project, States could fail to inform the public, include further public participation, or offer proper judicial remedies—all legal institutions that have already been thoroughly examined by scholars and policymakers.[291] Here, I address two key procedural considerations for the current state of research and development of SAI technologies: information and public engagement.[292]

Ensuring transparency, inclusivity, and access to information allows affected communities to engage in discussions about the risks, benefits, and ethical considerations of SAI activities. For instance, recent surveys indicate that the most publicly supported SRM policies at the domestic level are those with an informational purpose.[293] This is essential, especially at the current stage of SAI development where, despite the increasing research, much of the public debate still revolves around moral and ethical constraints, requiring more information.[294]

275. Anthony C. Jones et al., *Regional Climate Impacts of Stabilizing Global Warming at 1.5 K Using Solar Geoengineering*, 6 Earth's Future 230 (2018); Huynh & McNeill, *supra* note 7, at 130.
276. Jones et al., *supra* note 275; Ben Kravitz et al., *Comparing Different Generations of Idealized Solar Geoengineering Simulations in the Geoengineering Model Intercomparison Project (GeoMIP)*, 21 Atmospheric Chemistry & Physics 4231 (2021).
277. Simone Tilmes et al., *Effects of Different Stratospheric SO_2 Injection Altitudes on Stratospheric Chemistry and Dynamics*, 123 JGR Atmospheres 4654 (2018).
278. Huynh & McNeill, *supra* note 7, at 131-32.
279. WMO, *supra* note 5, at 361.
280. *Id.* at 361-63 (on the specific side environmental impacts of SRM and SAI).
281. Simone Tilmes et al., *The Hydrological Impact of Geoengineering in the Geoengineering Model Intercomparison Project (GeoMIP)*, 118 JGR Atmospheres 11036 (2013).
282. Charles G. Gertler et al., *Weakening of the Extratropical Storm Tracks in Solar Geoengineering Scenarios*, 47 Geophysical Rsch. Letters e2020GL087348 (2020); WMO, *supra* note 5, at 363.
283. Daniele Visioni et al., *What Goes Up Must Come Down: Impacts of Deposition in a Sulfate Geoengineering Scenario*, 15 Env't Rsch. Letters 094063, at 20 (2020); WMO, *supra* note 5, at 363.
284. WMO, *supra* note 5, at 363; Peer Johannes Nowack et al., *Stratospheric Ozone Changes Under Solar Geoengineering: Implications for UV Exposure and Air Quality*, 16 Atmospheric Chemistry & Physics 4191 (2016).
285. G.A. Res. 76/300, *supra* note 132, pmbl.; WMO, *supra* note 5, at 363; Simone Tilmes et al., *Impact of Very Short-Lived Halogens on Stratospheric Ozone Abundance and UV Radiation in a Geo-Engineered Atmosphere*, 12 Atmospheric Chemistry & Physics 10945 (2012).
286. *See infra* Sections V.A and V.C.
287. *See supra* Section III.B.
288. UNEP et al., *supra* note 137, at 9.
289. *See supra* Section III.B.
290. Reynolds, *supra* note 10, at 112; Stephens et al., *supra* note 12, at 1161; Shepherd, *supra* note 41, at 42; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 119-23.
291. *See supra* Section III.B.
292. *See A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 128-32 (analyzing the procedural aspect of seeking redress for a human rights violation through a judicial remedy).
293. Baum et al., *supra* note 11, at 10.
294. Christopher J. Preston, *Carbon Emissions, Stratospheric Aerosol Injection, and Unintended Harms*, 31 Ethics & Int'l Affs. 479, 479-81 (2017); Georges Alexandre Lenferna et al., *Relevant Climate Response Tests for Stratospheric Aerosol Injection: A Combined Ethical and Scientific Analysis*, 5 Earth's Future 577, 583-88 (2017).

Another procedural dimension is the emphasis on meaningful public participation in environmental decisionmaking processes,[295] especially for deciding on SAI regulatory frameworks and experimentation endeavors.[296] Public engagement mechanisms are of the utmost importance to increasing the legitimacy of SAI policies.[297] In fact, it is proven that "acknowledging science's political entanglements upstream in the innovation process can enhance the substance and democratic legitimacy of science itself."[298]

Still, once SAI moves from research to deployment, "it is unclear how the public might meaningfully continue to participate in the decision-making process."[299] Specific mechanisms by which to include public engagement will vary according to each legal culture and political arrangements.[300] In this regard, a key issue is to broaden the scope of public participation, acknowledging the many ways in which knowledge is produced around the world.[301] The following part delves into how to develop public engagement mechanisms in SAI research and deployment according to the human right to a healthy environment and a just transition framework.[302]

V. How to Ensure a Human Rights and Just Transition Approach in SAI Research and Deployment

Can we manage to deploy SAI under a human rights-based approach that echoes the call for a just transition? What is the pathway? Could it be through EIAs, the precautionary principle, and a clear international governance body?

As SAI remains an emerging technology, there are numerous legal issues to address in creating potential regulation. Current legal questions around SRM delve into its costs, potential hazards, governance frameworks, and moral considerations associated with its research and deployment.[303] Literature analyzing these problems from a just transition and the right to a healthy environment perspectives is rare.[304] Despite the politically charged debate around SAI development,[305] this part explores the legal normative issues arising within SAI development worldwide.

As explored in the previous part, there are many potential collisions between the research and deployment of SAI and a human rights-based and just transition framework. In this part, I analyze some of these questions from an international environmental legal perspective, focusing on international environmental principles, impact assessment, governance bodies, and public engagement. Some of these issues have already been commented on by other scholars and practitioners in the literature; however, most of them remain largely unexplored.[306]

A. *Environmental Principles*

1. The Precautionary Principle

General principles of international environmental law establish the parameters for the discussion on whether to move forward with these endeavors.[307] Given the uncertainties and potential irreversibility of SAI's impacts, procedural safeguards such as thorough risk assessments, monitoring mechanisms, and international governance frameworks are essential to uphold the precautionary principle and minimize harm. The lack of sufficient scientific evidence, the need for more experimentation, and the call for innovative and effective technologies to address peak temperatures turn this issue into a highly contested debate.

SAI technologies are still in their infancy, lacking sufficient research on their environmental impacts.[308] For instance, there is still uncertainty about how much aerosol injection would be needed to reach a sufficient cooling effect that prevents peak temperatures.[309] Therefore, experts call for a nuanced regulatory approach and to "balance societal risks with principles of freedom of scientific inquiry."[310]

295. *E.g.*, Fitzmaurice, *supra* note 138, at 655; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 119 ("The participation of individuals and communities in decision-making that impacts their lives, or threatens to do so, is also key to a human rights framework and undergirds the procedural aspects of the approach.").
296. Rayner et al., *supra* note 12, at 505-06; Daniel Bodansky, *Governing Climate Engineering: Scenarios for Analysis* 6 (Harvard Project on Climate Agreements, Discussion Paper No. 11-47, 2011).
297. *Political Legitimacy in Decisions About Experiments in Solar Radiation Management*, *supra* note 44, at 149-52; Frumhoff & Stephens, *supra* note 24, at 5-9.
298. Flegal et al., *supra* note 3, at 404; Rayner et al., *supra* note 12, at 505.
299. Bodansky, *supra* note 296, at 6.
300. Rayner et al., *supra* note 12, at 506.
301. David E. Winickoff et al., *Engaging the Global South on Climate Engineering Research*, 5 Nature Climate Change 627, 627-29 (2015).
302. *See infra* Section V.C.
303. IPCC, *supra* note 28, at 89.
304. *See supra* Part IV.
305. *E.g.*, Virgoe, *supra* note 256, at 106-09 (identifying four sociopolitical characteristics of geoengineering that might influence an appropriate governance regime); David Keith, A Case for Climate Engineering 121-56 (2013).
306. Chiara Armeni & Catherine Redgwell, *International Legal and Regulatory Issues of Climate Geoengineering Governance: Rethinking the Approach* 15 (Climate Geoengineering Governance, Working Paper No. 21, 2015) (Indeed, "[t]here is a wide body of literature discussing international norms likely to be relevant to the individual geoengineering techniques. Such review has largely focused on existing international treaties, against the backstop of customary international law rules and general principles.").
307. Daniel Bodansky, *May We Engineer the Climate?*, 33 Climatic Change 309, 312 (1996); Shepherd, *supra* note 41, at 40.
308. WMO, *supra* note 5, at 345, 349; Temple, *supra* note 1 ("'The current state of science is not good enough . . . to either reject, or to accept, let alone implement' solar geoengineering, wrote Janos Pasztor, executive director of the Carnegie Climate Governance Initiative . . . ."); Huynh & McNeill, *supra* note 7, at 134-35; National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 184, 191-257 ("A central goal of SG [solar geoengineering] research is to understand the relative risks and benefits of different SG strategies and the distribution of these risks and benefits.").
309. WMO, *supra* note 5, at 339; Ben Kravitz et al., *Comparing Surface and Stratospheric Impacts of Geoengineering With Different SO_2 Injection Strategies*, 124 JGR Atmospheres 7900, 7914 (2019).
310. UNEP, *supra* note 3, at 25; Shepherd, *supra* note 41, at 37.

In this context, the case of SAI is a prime example of technological innovation that must develop and transition in an equitable manner.[311] Consequently, the human right to science is essential.[312] This right has been recognized by the Universal Declaration of Human Rights and the International Covenant on Civil and Political Rights, among other international instruments.[313] The right emphasizes a willingness to recognize science as a public good, promoting international cooperation and access to the benefits of scientific advancement and its applications.[314] Despite its unclear content,[315] there are many elements of the right to science that could influence the research and deployment of SAI, such as the need to ensure that essential technological innovations are widely accessible, while considering the priorities of marginalized communities and the respect, protection, and promotion of scientific freedom.[316]

Accordingly, some argue that this right could be fundamental in shaping a normative framework for geoengineering development, since it would promote accountability and public engagement, while dealing with technical risks in research and development.[317] A particular advantage of the right to science would be that "it applies regardless of the scale, duration or environmental impact of the research project."[318] Although this discussion goes beyond the scope of this Article, it must be noted that the scientific community is arguing for a moderate, conscious, and transitory climate engineering response.[319] Such an approach aims to mitigate the most severe impacts of climate change in the forthcoming decades, prior to the complete implementation of mitigation and adaptation measures.

The precautionary principle demands that "[w]here there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[320] However, its implementation has raised many issues throughout the years.[321] Scientific researchers and human rights scholars have already expressed their concern that experimentation on SAI technologies without a complete understanding of their consequences contradicts this principle, "which must be applied in the case of a technology that would modify the atmosphere and increases concerns about potential deployment without understanding the risks."[322]

However, the great paradox when deciding how to apply this principle lies in the fact that failing to implement timely actions to address peak climate change impacts could result in irreversible damage. This raises the question of whether the principle ultimately supports immediate action or a more cautious approach, making it unclear "which way the principle cuts."[323] SAI could be seen as a mitigation technology that might curtail harms. It is also, however, a new technology with substantial new risks.

If given sufficient leeway, SAI could become the most cost-effective measure to prevent environmental degradation.[324] Thus, when assessing whether to allow SAI development, there must be a broader comparison between the ongoing climate change impacts, if not mitigated by SAI, and the risks of SAI deployment.[325] As Jutta Wieding et al. put it: "The connection to human rights makes it clear: the bigger the impending damage in its occurrence, the more ambitious the necessary protection measures have to be."[326]

Closely related is the idea of mainstreaming the human right to a healthy environment throughout the institutions and regulations that could potentially address SAI.[327] Thus, when balancing regulations to allow or prohibit SAI, the risks and impacts of climate change on the enjoyment of the right to a healthy environment and a just transition should be weighed. Indeed, the benefits of SAI deployment in the short term could contribute to the enjoyment of the right to a healthy environment as well as the conditions for exercising other human rights.[328]

311. Harrington, *supra* note 65, at 215.
312. *E.g.*, Kristin Barham & Anna-Maria Hubert, *The International Human Right to Science and Its Application to Geoengineering Research and Development*, Univ. Calgary: ABLawg (Sept. 7, 2016), https://ablawg.ca/2016/09/07/international-human-right-to-science/ ("Geoengineering will touch on many human rights, but it is the so-called 'right to science' that best functions as a normative framework for informing research governance.").
313. G.A. Res. 217 (111) A, *supra* note 149, art. 27; International Covenant on Civil and Political Rights, *supra* note 149, art. 15.
314. *The Right to Science and Culture*, *supra* note 26, at 183; Audrey R. Chapman, *Towards an Understanding of the Right to Enjoy the Benefits of Scientific Progress and Its Applications*, *in* Economic, Social, and Cultural Rights 375 (Manisuli Ssenyonjo ed., Routledge 2017).
315. Farida Shaheed (Special Rapporteur in the Field of Cultural Rights), *The Right to Enjoy the Benefits of Scientific Progress and Its Applications*, ¶ 1, U.N. Doc. A/HRC/20/26 (May 14, 2012); Barham & Hubert, *supra* note 312, at 2.
316. Shaheed, *supra* note 315, ¶ 74.
317. Barham & Hubert, *supra* note 312, at 5.
318. *Id.*
319. *E.g.*, Keith, *supra* note 305, at 159-74; Pinker, *supra* note 38, at 153; David W. Keith & Douglas G. MacMartin, *A Temporary, Moderate, and Responsive Scenario for Solar Geoengineering*, 5 Nature Climate Change 201 (2015); Oliver Morton, The Planet Remade: How Geoengineering Could Change the World 369-75 (2015).
320. *Rio Declaration*, *supra* note 160, princ. 15.
321. *E.g.*, Elizabeth Fisher et al., Implementing the Precautionary Principle: Perspectives and Prospects (1st ed. 2006) (More than 20 authors analyze the challenges of implementing the precautionary principle in public decisionmaking, and specific fields such as climate change, biodiversity conservation, and nanotechnology, among others, illustrating how difficult it is to apply this principle in practice.); COMEST, *supra* note 53, at 25-45.
322. Andersen & Gonzalez, *supra* note 7, at 188; *see* Lauren Hartzell-Nichols, *Precaution and Solar Radiation Management*, 15 Ethics Pol'y & Env't 158 (2012); UNHRC, *supra* note 14, at 10.
323. Bodansky, *supra* note 296, at 15; *see* Reynolds, *supra* note 10, at 77; Puno, *supra* note 164, at 10749; *but see* Taleb et al., *supra* note 53, at 1 (regarding prior discussions on GMOs, many authors suggest that "the [precautionary principle] should be evoked only in extreme situations: when the potential harm is systemic [rather than localized] and the consequences can involve total irreversible ruin, such as the extinction of human beings or all life on the planet").
324. *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 112.
325. Shepherd, *supra* note 41, at 38. *See supra* Section IV.C.
326. Wieding et al., *supra* note 228, at 11.
327. *E.g.*, Jacqueline Peel, *The "Rights" Way to Democratize the Science-Policy Interface in International Environmental Law? A Reply to Anna-Maria Hubert*, 31 Eur. J. Int'l L. 657, 663 (2020) ("[R]ights-based arguments focused on the inequitable distribution of benefits and risks might helpfully supplement a precautionary regulatory approach.").
328. *See supra* Section IV.C.

2. The No-Harm Principle and the Principle of Prevention

A key legal issue surrounding UNGA recognition of the human right to a healthy environment is its extraterritoriality. This would impose on all States a "duty to refrain from causing environmental harm outside their own territory."[329] This is a consequence of Principle 21 of the Stockholm Declaration[330] and Principle 2 of the Rio Declaration, which constitute the basis for the general principle of not causing transboundary environmental harm, or the no-harm principle.[331] This principle is complemented by the principle of prevention, which also constitutes customary international law and emphasizes the obligation of States to prevent extraterritorial environmental damage.[332] However, this prevention goes beyond the mere transboundary damage caused to other States' sovereign rights, and States have a general obligation to prevent environmental damage.[333]

How can these duties complement the legal framework of human rights and a just transition for SAI? First, given that SAI's effects are likely to vary across different jurisdictions, States must refrain from activities that exacerbate climate change impacts, as these could lead to transboundary consequences and undermine the enjoyment of the human right to a healthy environment.[334] However, considering the uncertainty surrounding SAI's environmental impacts, it remains unclear how these principles should be applied in practice, creating a challenge in determining their exact implications.

Considering the potential benefits of SAI development, the position of scholars arguing for a solar geoengineering non-use agreement would not be that clear.[335] These authors suggest that scientific research in this field violates the no-harm principle, so it should be banned.[336] As the scientific community states, it is not that easy; we need more research for a better understanding of its consequences before arriving at such a decision.[337]

One of the most influential reports on this matter is the 2021 work led by the International Law Commission of the U.N., which drafted guidelines on protection of the atmosphere.[338] Regarding the no-harm principle and SAI research and deployment in the stratosphere—part of the atmosphere—States would have an obligation to protect the atmosphere, particularly by "exercising due diligence in taking appropriate measures, in accordance with applicable rules of international law, to prevent, reduce or control atmospheric pollution and atmospheric degradation."[339] Indeed, this would apply to SAI research and deployment, since it would imply polluting the atmosphere through massive sulfur releases. Moreover, these guidelines engage with the global and transboundary dimension of atmospheric intervention,[340] by defining atmospheric degradation,[341] as well as atmospheric pollution.[342]

Another related issue is how to allocate specific responsibilities and liabilities for transboundary environmental damage caused by SAI research and deployment.[343] Since these technologies aim to modify solar radiation, there is uncertainty about whether all States will bear its potential side effects equally.[344] These disparities can cause potential geopolitical tensions.[345] As the comments of the International Law Commission state, the existence of an obligation to prevent transboundary harm as customary international law in the case of global atmospheric pollution "is still somewhat unsettled."[346]

Currently, there are no specific liability regimes for SAI.[347] Some authors are already calling to settle legal compensation mechanisms before delving into large-scale SAI interventions.[348] The challenge ahead is important, since SAI might test the applicability of traditional customary rules on State responsibility.[349] Indeed, such a scenario could turn even more complex if the human rights institutional framework comes into practice, for instance, through current climate litigation efforts.[350]

A key advisory opinion by the Inter-American Court of Human Rights from 2017 could steer the path in this discussion over liability regimes.[351] The court, responding to a request from the Colombian government on State obligations in relation to the environment in the context of the protection and guarantee of the rights to life and to personal integrity, established under the American Conven-

329. UNHRC, *supra* note 14, at 11.
330. G.A. Res. 76/300, *supra* note 132.
331. *Rio Declaration*, *supra* note 160, princ. 2; Philippe Sands & Jacqueline Peel, Principles of International Environmental Law 195-200 (3d ed. 2012); Stephen C. McCaffrey et al., International Law for the Environment 154-80 (2015); Nicolas de Sadeleer, Environmental Principles: From Political Slogans to Legal Rules 86-89 (2d ed. 2020).
332. Atapattu, *supra* note 140, at 63, 90; de Sadeleer, *supra* note 331, at 88.
333. de Sadeleer, *supra* note 331, at 88.
334. Atapattu, *supra* note 140, at 89.
335. Gupta et al., *supra* note 267, at 10.
336. *Id.*
337. *See supra* Section V.A.1.
338. U.N. International Law Commission, *Report of the International Law Commission Seventy-Second Session*, U.N. Doc. A/76/10, ch. IV (Aug. 6, 2021).
339. *Id.* guideline 3.
340. *Id.* guideline 3, cmt. (2).
341. *Id.* guideline 1 ("[A]lteration by humans, directly or indirectly, of atmospheric conditions having significant deleterious effects of such a nature as to endanger human life and health and the Earth's natural environment.").
342. *Id.* ("[T]he introduction or release by humans, directly or indirectly, into the atmosphere of substances or energy contributing to significant deleterious effects extending beyond the State of origin of such a nature as to endanger human life and health and the Earth's natural environment.").
343. IPCC, *supra* note 28, at 123; Reynolds, *supra* note 10, at 87.
344. WMO, *supra* note 5, at 355-70; McCaffrey et al., *supra* note 331, at 544; Knox, *supra* note 151, at 16.
345. Morrissey, *supra* note 30, at 4-6.
346. U.N. International Law Commission, *supra* note 338, guideline 3, cmt. 8.
347. Barbara Saxler et al., *International Liability for Transboundary Damage Arising From Stratospheric Aerosol Injections*, 7 Law Innovation & Tech. 112, 118-31 (2015).
348. Saxler et al., *supra* note 347; Lauren Packard, *Designing an International Liability Regime to Compensate Victims of Solar Radiation Management*, 30 Env't Claims J. 71 (2018).
349. David Reichwein et al., *State Responsibility for Environmental Harm From Climate Engineering*, 5 Climate L. 142 (2015); Saxler et al., *supra* note 347.
350. *E.g.*, Jacqueline Peel, *Issues in Climate Change Litigation*, 5 Carbon & Climate L. Rev. 15, 24 (2011); Jacqueline Peel & Hari M. Osofsky, Climate Change Litigation 9-16 (2015); Joana Setzer & Lisa C. Vanhala, *Climate Change Litigation: A Review of Research on Courts and Litigants in Climate Governance*, 10 WIREs Climate Change e580, at 12-13 (2019).
351. The Environment and Human Rights, Advisory Opinion OC-23/17, Inter-Am. Ct. H.R. (ser. A) No. 23, ¶ 104 (Nov. 15, 2017).

tion on Human Rights that States are obliged to prevent transboundary environmental damage that could affect the human rights of people outside their territory.[352] The opinion also specifies the obligations emanating from this duty regarding the right to a healthy environment from its procedural and substantive perspectives, and the right to life and health.[353]

B. EIA

At the international level, EIAs are an instrument to assess "proposed activities that are likely to have a significant adverse impact on the environment."[354] A prior EIA on the potential impacts of a project or policy, including its repercussions on the enjoyment of human rights, could "avoid undertaking or authorizing actions with environmental impacts that interfere with the full enjoyment of human rights."[355] Indeed, EIA procedures could directly address the core scientific uncertainties surrounding SAI decisionmaking and the potential risks it poses to the environment. EIAs have a unique "ability to absorb other concerns, be they environmental, economic, or social—and thus encourage recognition of diverse concerns, and the connections between them."[356]

As a procedural norm or principle of international environmental law, EIA could inform the governing bodies and structures around SAI research and deployment.[357] Indeed, EIA has been recognized as a way of enhancing the procedural governance of SRM.[358] Conducting these assessments is also one way of implementing a preventive approach, since it identifies the nature and extension of the associated risks, alternatives, and potential evidence or mitigation measures.[359] Even more, public engagement mechanisms could also be channeled through these venues. Thus, an EIA is one of the most useful mechanisms to advance procedural and substantive aspects of the right to a healthy environment in SAI research and deployment.

The key question that arises is whether and how to conduct an EIA for SAI projects that could potentially affect the stratosphere on a global scale.[360] Some authors suggest beginning with a soft-law approach, encouraging voluntary commitments to conduct an EIA of SRM activities that could have transboundary impacts.[361] The scope of such EIAs should be broad, aiming to increase public acceptability, transparency, and trust in the projects.[362]

Among the guidelines drafted by the International Law Commission of the U.N. on the protection of the atmosphere, there are two key considerations connecting SAI and EIA.[363] First, emerging from the obligation to protect the atmosphere,[364] the "intentional large-scale modification of the atmosphere should only be conducted with prudence and caution, and subject to any applicable rules of international law, including those relating to environmental impact assessment."[365] Consequently, States would have to conduct an EIA of "proposed activities under their jurisdiction or control which are likely to cause significant adverse impact on the atmosphere in terms of atmospheric pollution or atmospheric degradation."[366] In this regard, it is interesting to note that the guidelines are not legally enforceable; however, they aim to be widely disseminated, including among States and international organizations, and adhered to as much as possible.[367]

From a procedural perspective of the right to a healthy environment, EIAs have been recognized as a participatory democracy mechanism, thus partly fulfilling a human rights call for participation in assessing an environmentally risky activity or project under consideration.[368] In this vein, the U.N. Special Rapporteur on Human Rights and the Environment suggests that EIAs "should also examine the possible effects of the environmental impacts of proposed projects and policies on the enjoyment of all relevant rights, including the rights to life, health, food, water, housing and culture."[369] This idea sparks another conversation on whether EIAs should incorporate a human rights analysis or if this could be conducted in tandem with an HRIA.[370]

C. International Governance Body

1. A Missing Part

There are no institutional frameworks to govern SAI research beyond the domestic frameworks that oversee other types of scientific or engineering research.[371] The main

352. Organization of American States, American Convention on Human Rights, Nov. 22, 1969, O.A.S.T.S. No. 36, 1144 U.N.T.S. 123; The Environment and Human Rights, Advisory Opinion OC-23/17, Inter-Am. Ct. H.R. (ser. A) No. 23, ¶ 101 (Nov. 15, 2017).
353. The Environment and Human Rights, Advisory Opinion OC-23/17, Inter-Am. Ct. H.R. (ser. A) No. 23, ¶¶ 104, 242 (Nov. 15, 2017).
354. *Rio Declaration*, *supra* note 160, princ. 17.
355. *Report of the Special Rapporteur*, *supra* note 20, at 11.
356. Jane Holder, Environmental Assessment: The Regulation of Decision Making 59 (1st ed. 2006).
357. *Id.* at 53; McCaffrey et al., *supra* note 331, at 213-21; Sands & Peel, *supra* note 331, at 601-23; Chandra Bhushan & Tarun Gopalakrishnan, International Forum for Environment, Sustainability, and Technology, Governing Solar Radiation Modification Under the Vienna Convention 19-20 (2023).
358. Nigel Moore et al., *Procedural Governance of Field Experiments in Solar Radiation Management* (Institute for Advanced Sustainability Studies, IASS Working Paper, 2015); Neil Craik, *International EIA Law and Geoengineering: Do Emerging Technologies Require Special Rules?*, 5 Climate L. 111, 119 (2015).
359. Sikina Jinnah et al., *Governing Climate Engineering: A Proposal for Immediate Governance of Solar Radiation Management*, 11 Sustainability art. 3954, at 6 (2019); de Sadeleer, *supra* note 331, at 98-101; McCaffrey et al., *supra* note 331, at 213-17.
360. Craik, *supra* note 358, at 119, 123-24.
361. *Id.* at 139.
362. *Id.* at 139-41; *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 120.
363. U.N. International Law Commission, *supra* note 338.
364. *Id.* guideline 3.
365. *Id.* guideline 7.
366. *Id.* guideline 4.
367. *Id.* ¶ 37. *See infra* Section V.C.2 ("Other alternatives").
368. Holder, *supra* note 356, at 292.
369. *Report of the Special Rapporteur*, *supra* note 20, at 12.
370. Burns, *supra* note 5, at 23.
371. UNEP, *supra* note 3, at 22; Shepherd, *supra* note 41, at 60; *see* Mike Hulme, Can Science Fix Climate Change?: A Case Against Climate Engineering xii (2014) (arguing that climate engineering would

issue with existing regulations is that, given the novelty of solar geoengineering technologies, they do not address SAI particularities.[372] Thus, scattered legal frameworks address some SAI components. There are five international treaties and nine U.N. resolutions, draft resolutions, and MEA or COP decisions relevant to SRM.[373]

To ensure the observance of human rights within SAI development, we need a designated body to oversee its research and deployment at a global scale.[374] We need an international legal framework to ensure geoengineering activities do not infringe on the global community's right to a healthy environment. Certainly, as the Office of the High Commissioner for Human Rights (OHCHR) and the UNHRC have recognized, there is an obligation among countries to cooperate as widely as possible, given the global impact of climate change.[375]

However, the novelty of the technology and the ongoing moral debate around its research have delayed any clear decision about it. The deployment of SAI touches on ethical and legal issues related to environmental integrity, intergenerational equity, and the precautionary principle. As Daniel Bodansky notes, governing geoengineering involves "developing norms to guide scientific research, allocating jurisdiction among states to regulate individuals, elaborating rules that constrain state behavior, establishing procedures to limit conflict among states, and so on."[376]

The implementation of SAI raises questions about global governance, as SAI effects would not be limited by national boundaries. Indeed, governance issues have been tagged as "particularly challenging, especially as unilateral action might lead to significant effects and costs for others."[377] Therefore, decisionmaking processes must ensure that all communities and countries have a voice, particularly those most vulnerable to climate change and least equipped to respond to potential negative impacts of SAI.[378]

2. Governance Proposals

A first step to advance the solar geoengineering agenda from a human rights perspective could be to define a clear governing body. A governing body might contribute to the timely development of SRM technologies and an appropriate regulatory framework to enforce the observance of the human right to a healthy environment as affected by these technologies. Thus, States should agree on the need for a new governance structure and its specific configuration.[379] There are two prominent alternatives to address this governance question from a U.N. multilateral perspective.[380]

☐ *Creating a solar radiation management convention*. The first alternative to govern SRM and SAI endeavors is to push for a new MEA addressing these technologies. The most obvious setback is the time it takes to reach a consensus to start the negotiations on a new agreement. For instance, the most recent experience with the plastics treaty negotiations shows that it can take years to produce draft regulations.[381] Still, to cut peak temperatures arising from climate change-caused increasing temperatures, SAI—if used—must be developed in a shorter period of time.

Another question is the appropriate scope of a potential new MEA. Unquestionably, this new agreement must acknowledge the human right to a healthy environment from its procedural and substantive content. Moreover, if the intention is to build a broad framework addressing the issue of stratosphere intervention, this could range from regulating solar geoengineering techniques to other related challenges such as space debris.[382]

☐ *Harnessing a preexisting accord*. Another option to achieve international governance is to explicitly regulate SAI technologies under an existing MEA. Some authors suggest regulating geoengineering—SRM and CDR included—under the same MEA, such as the CBD or the UNFCCC.[383] Still, each specific geoengineering technique affects different components of the environment.[384] For instance, unlike marine cloud brightening or ocean fertilization, SAI would mainly intervene the stratosphere.[385] Thus, considering the technical and timing constraints, a fragmented approach seems the most feasible and efficient regulatory technique, instead of a one-size-fits-all approach.[386]

To regulate SAI, I support taking advantage of the existing technical capacity under the Vienna Convention and its Montreal Protocol.[387] As experts point out, "[t]he

be ungovernable because there is no feasible mechanism to decide the world's temperature).

372. Kerryn Brent et al., *From Informal to Formal Governance of Solar Radiation Management*, Climate Pol'y 14-15 (2024).
373. UNEP, *supra* note 3, annex 5; Wieding et al., *supra* note 228, at 8-10; UNHRC, *supra* note 14, at 7-9; Virgoe, *supra* note 256, at 109-11.
374. Jinnah et al., *supra* note 359, at 8; Flegal et al., *supra* note 3, at 411.
375. UNHRC Res. 18/22, Human Rights and Climate Change, at 2 (Oct. 17, 2011).
376. Bodansky, *supra* note 296, at 30; Bodansky, *supra* note 307, at 309-10.
377. IPCC, *supra* note 28, at 89.
378. UNHRC Res. 18/22, *supra* note 375, at 2:

> [R]esponses to climate change should be coordinated with social and economic development in an integrated manner with a view to avoiding an adverse impact on the latter, taking into full account the legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty.

379. UNEP, *supra* note 3, at 22; Andersen & Gonzalez, *supra* note 7, at 189.
380. Virgoe, *supra* note 256, at 112-15; Reynolds, *supra* note 10, at 62; UNEP, *supra* note 3, at 22; Armeni & Redgwell, *supra* note 306, at 27-28.
381. *See* UNEA Res. 5/14, End Plastic Pollution: Towards an International Legally Binding Instrument (Mar. 7, 2022) (After negotiating during 2021, before the States convened on March 2022 for agreeing to start negotiating a plastics treaty, this UNEA resolution established the ambition for the intergovernmental negotiating committee to complete a final draft by the end of 2024, which failed.).
382. UNEP, *supra* note 3, at 22.
383. Wieding et al., *supra* note 228, at 8-10; Puno, *supra* note 164, at 10747-48; Shepherd, *supra* note 41, at 39-41.
384. UNEP, *supra* note 3, at 11-13.
385. Huynh & McNeill, *supra* note 7, at 118-19; UNEP, *supra* note 3, at 11-13.
386. Armeni & Redgwell, *supra* note 306, at 15-19; Grasso, *supra* note 24, at 221; Puno, *supra* note 164, at 10751.
387. *E.g.*, Bhushan & Gopalakrishnan, *supra* note 357, at 6-7 (one of the most recent and extensive analyses proposing the Vienna Convention and its Montreal Protocol to regulate SAI and SRM); Reynolds, *supra* note 10, at 96-97.

tasks essential for climate intervention assessment and monitoring are well within the Montreal Protocol panels' expertise."[388] Certainly, outdoor research and deployment of SAI are projected to take place within the same area of influence as the ozone layer.[389] SAI might have significant impacts on the ozone layer by depleting stratospheric ozone or even "delaying recovery of the ozone layer."[390] Therefore, taking advantage of the existing institutional capacities under the convention and its protocol, such as the ozone research managers, would save valuable time.[391]

The ongoing research and work led by the scientific panel of the Montreal Protocol on the impacts of SAI on the stratosphere is exemplary.[392] Therefore, the Vienna Convention and its protocol not only have technical capacity and experience, but also serve as "a framework for cooperation on research, information exchange, national regulation and standard-setting. It emphasizes the importance of cooperation in scientific research, scientific assessment and systematic monitoring of the ozone layer."[393] All of these attributes could benefit study and deliberation over SAI research and deployment.[394]

As already stated, the key issue surrounding SAI governance is its scientific uncertainty. The Vienna Convention also emerged out of a highly uncertain terrain over the impacts of aerosols on ozone depletion.[395] Thus, another reason to govern SAI under the architecture of the Vienna Convention, and its Montreal Protocol, is its capability to successfully face scientific uncertainty. Indeed, in the case of ozone-depleting substances, "high scientific uncertainty led to flexible regimes with initially small memberships that were expanded and legalized over time."[396] This is precisely the case with SAI.

☐ *Exploring other alternatives*. Apart from prescriptive approaches, there are suggestions for less compulsory frameworks.[397] Alternatives range from a high-level commission, such as a World Commission on Climate Engineering,[398] to a soft-law approach through the development of voluntary codes or principles.[399] These voluntary norms would promote a collaborative framework for building geoengineering governance comprising reporting duties, transparency, and even the sharing of research data.[400] For instance, among the most influential geoengineering declarations are the guidelines on the protection of the atmosphere, drafted by the International Law Commission of the U.N.,[401] or the Oxford Principles, drafted by an ad hoc group of British academics on geoengineering research and deployment.[402]

The Oxford Principles were the base for the formulation of a voluntary code of conduct for SRM research in 2010, with the participation of more than 200 scientists.[403] They argue for understanding geoengineering as a public good and focus on public engagement, transparency, independent assessment, and the need for governance frameworks.[404] However, there is no mention of human rights, at least not explicitly. It would be fair to assume that the authors understood that if the five suggested principles were observed, then human rights would be respected as well.

For instance, the second principle requires prior notification to affected persons by SRM research, and the fourth principle advocates for undergoing prior impact assessments.[405] Despite its lack of enforceability, I suggest adding an additional principle to clearly acknowledge the duty to observe human rights, especially the substantive right to a healthy environment, during research and deployment. Still, the challenge is to "'operationalise' these abstract principles in institutional and national contexts,"[406] as well as to reflect the concerns from the Global South.[407]

Human rights institutional frameworks could also help enforce such considerations in SAI endeavors, including regional human rights courts and other specialized frameworks.[408] Still, all these suggestions should be taken with a grain of salt. As John Virgoe asks, "What would be the

388. Andersen & Gonzalez, *supra* note 7, at 183; Bodansky, *supra* note 296, at 17-18, 20, 30; Bhushan & Gopalakrishnan, *supra* note 357, at 6 ("There is, therefore, no ambiguity around the fact that the Vienna Convention is an appropriate convention to govern those SRM that affect the ozone layer, specifically SAI."); *International Legal Regimes and Principles Relevant to Geoengineering*, *in* Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks, *supra* note 26, at 196.

389. Montreal Protocol Decision XXXV/4: Stratospheric Aerosol Injection and Protection of the Ozone Layer (2023).

390. *Id.*

391. UNEP Ozone Secretariat, *Ozone Research Managers*, https://ozone.unep.org/taxonomy/term/514 (last visited Dec. 5, 2024).

392. WMO, *supra* note 5, at 323.

393. Bhushan & Gopalakrishnan, *supra* note 357, at 10.

394. *E.g.*, National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 185 ("Science agencies in countries that are funding SG research should advance international cooperation by coordinating with other national and regional level SG research programs.").

395. Charles F. Sabel & David G. Victor, Fixing the Climate: Strategies for an Uncertain World 22-26 (2022).

396. Ian D. Lloyd & Michael Oppenheimer, *On the Design of an International Governance Framework for Geoengineering*, 14 Glob. Env't Pol. 45, 58 (2014); *see* Sabel & Victor, *supra* note 395, at 26-31.

397. UNEP, *supra* note 3, at 23 (recounting several informal collaborative frameworks for the development of SRM research); Armeni & Redgwell, *supra* note 306, at 18-19.

398. Edward A. Parson, Centre for International Governance Innovation, Starting the Dialogue on Climate Engineering Governance: A World Commission 4-5 (2017); Jinnah et al., *supra* note 359, at 5-8; *see also* Reynolds, *supra* note 10, at 209 (proposing a similar institution called Solar Geoengineering Organization, similar to the International Atomic Energy Agency).

399. *See* Virgoe, *supra* note 256, at 116-17 (This can be assimilated to the idea of a consortium.); Bodansky, *supra* note 296, at 22 ("[S]elf-regulation by scientists—for example, through the development of research codes of conduct—may be more feasible, at least initially."); National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 133-38; Brent et al., *supra* note 372, at 8-14.

400. UNEP, *supra* note 3, at 22; Rayner et al., *supra* note 12, at 503.

401. U.N. International Law Commission, *supra* note 338.

402. Rayner et al., *supra* note 12, at 500.

403. UNEP, *supra* note 3, at 22.

404. *"Oxford Principles" Vital for Geoengineering Research*, Oxford Martin Sch. (Sept. 14, 2011), https://www.oxfordmartin.ox.ac.uk/news/201109-oxfordprinciples.

405. Oxford Martin School, *Oxford Geoengineering Programme*, https://www.oxfordmartin.ox.ac.uk/geoengineering (last visited Jan. 8, 2025).

406. Brent et al., *supra* note 372, at 14.

407. *Id.*

408. Svoboda et al., *supra* note 13, at 2; Bodansky et al., *supra* note 20, at 299-300.

chances of achieving a multilateral agreement to deploy geoengineering? On the face of it, not good."[409]

Alternatively, I also echo the idea that developing a detailed regulatory framework of SAI at this early stage of development could be counterproductive.[410] In this context, there could be a relaxation of the just transition and human rights-based approaches during the research and initial deployment of SAI.[411] Indeed, in this whole part, I work around three other components to incorporate this framework without locking in a rigid governance structure: environmental principles, public engagement, and EIA.

D. Public Engagement Mechanisms

"[D]irect political input to define the aims and objectives of geoengineering regulation and governance is lacking or absent."[412] It is critical to develop effective public engagement and transparent communication regarding the risks, benefits, and uncertainties of SAI.[413] Public participation in decisionmaking processes could assist with aligning environmental policies, including geoengineering initiatives, with societal values and the collective human right to a healthy environment, enhancing their democratic legitimacy.[414]

Public engagement should be included throughout the entire cycle of climate intervention technologies, from their inception to deployment.[415] Indeed, public engagement should also be included in upstream regulatory procedures to broaden the range of perspectives on normative discussions around SAI.[416] For instance, the discussion on a governance body must be as inclusive as possible.[417] The decisionmaking on how to govern solar geoengineering and SAI must include all relevant stakeholders, including representatives from the Global South, which have been displaced from this conversation.[418]

A good example of the tensions emerging within SAI and public engagement is the widespread opposition to its outdoor experimentation around the world. Here, I comment on a few recent cases. For instance, in 2012, a U.K. team planned the first outdoor experiment, under the Stratospheric Particle Injection for Climate Engineering (SPICE) project.[419] This project involved a stakeholder engagement program, including interviews with nongovernmental organizations, other civil society actors, and scientists.[420] Still, the engagement program turned out to be insufficient, resulting in the cancellation of the experiment due to strong public opposition arguing insufficient public engagement, among other concerns.[421]

The most salient case is a recent project developed by Harvard University, entitled Stratospheric Controlled Perturbation Experiment (SCoPEx), which intends to further the understanding of SAI technologies.[422] Due to COVID restrictions, the project was moved from its intended location in New Mexico and an attempt was made to conduct its testing in Sweden. There, the project faced strong opposition from Indigenous Sámi communities, arguing that there was a lack of prior public consultation mechanisms on whether to conduct such an experiment or not.[423] The opposition was so massive that the developers decided to cancel.[424]

In 2024, another startup conducted an experiment in Baja California, Mexico.[425] It consisted of launching two weather balloons into the stratosphere to release sulfur dioxide.[426] However, this experiment was conducted without any public engagement process or notice at all.[427] Mexico responded that "the launch violated its national sovereignty,"[428] and began drafting regulations to ban solar geoengineering.[429]

409. Virgoe, *supra* note 256, at 113.
410. David G. Victor, *On the Regulation of Geoengineering*, 24 Oxford Rev. Econ. Pol'y 322, 330-32 (2008); Reynolds, *supra* note 10, at 198, 200 ("[T]oo strong a push for an early debate on international governance could result in a premature ban, taboo, or excessive regulation.").
411. *Accord* Wieding et al., *supra* note 228, at 13 (To prevent the necessity of a constantly repeated legal examination, many approaches resort to rather general criteria, because securing and creating collective structures of decisionmaking on a case-by-case basis ex ante is regarded as most promising.).
412. Flegal et al., *supra* note 3, at 413. *Accord* Stephens et al., *supra* note 12, at 1161.
413. Wylie A. Carr et al., *Public Engagement on Solar Radiation Management and Why It Needs to Happen Now*, 121 Climatic Change 567, 572-75 (2013).
414. Reynolds, *supra* note 10, at 28 ("Who decides whether, when, and how solar geoengineering might be implemented is arguably its leading social challenge."); Nick Pidgeon et al., *Deliberating Stratospheric Aerosols for Climate Geoengineering and the SPICE Project*, 3 Nature Climate Change 451, 455 (2013) ("A key concern for participants was that international governance and regulatory structures should be under development now to help shape geoengineering research such as the test bed, [Stratospheric Particle Injection for Climate Engineering (SPICE)] and future developments."); Carr et al., *supra* note 413, at 575; IPCC, *supra* note 21, at 1368; Frumhoff & Stephens, *supra* note 24, at 9; Grasso, *supra* note 24, at 223-24; Olawuyi, *supra* note 18, at 139.
415. Svoboda et al., *supra* note 13, at 11.
416. Flegal et al., *supra* note 3, at 413.
417. Simon Nicholson et al., *Solar Radiation Management: A Proposal for Immediate Polycentric Governance*, 18 Climate Pol'y 322, 331 (2018); UNEP, *supra* note 3, at 22; Armeni & Redgwell, *supra* note 306, at 15; *Geoengineering Is Everyone's Business*, *in* Geoengineering: Counteracting Climate Change, *supra* note 273, at 159 ("[P]ublic involvement in the design of governance itself needs to be front and centre in the development of geoengineering experiments.").
418. UNEP, *supra* note 3, at 22; UNHRC, *supra* note 14, at 16; Andersen & Gonzalez, *supra* note 7, at 189.
419. Jack Stilgoe et al., *Public Engagement With Biotechnologies Offers Lessons for the Governance of Geoengineering Research and Beyond*, 11 PLoS Biology 2 (2013).
420. *Id.* at 2-3.
421. *Id.* at 5.
422. Keutsch Group at Harvard, *SCoPEx: Stratospheric Controlled Perturbation Experiment*, https://www.keutschgroup.com/scopex (last visited Dec. 5, 2024).
423. Fialka & E&E News, *supra* note 48; *Why Did the Saami Council Oppose Harvard's SCoPEx Experiment?*, *supra* note 48; Haley Dunleavy, *An Indigenous Group's Objection to Geoengineering Spurs a Debate About Social Justice in Climate Science*, Inside Climate News (July 7, 2021), https://insideclimatenews.org/news/07072021/sami-sweden-objection-geoengineering-justice-climate-science/.
424. Fialka & E&E News, *supra* note 48; Dunleavy, *supra* note 423; *Why Did the Saami Council Oppose Harvard's SCoPEx Experiment?*, *supra* note 48; *An Update on SCoPEx*, Salata Inst. for Climate & Sustainability (Mar. 18, 2024), https://salatainstitute.harvard.edu/an-update-on-scopex/; *see generally* Sikina Jinnah et al., *Do Small Outdoor Geoengineering Experiments Require Governance?*, 385 Science 600 (2024).
425. Temple, *supra* note 1; Garrison, *supra* note 1.
426. Temple, *supra* note 1.
427. *Id.*
428. Garrison, *supra* note 1.
429. *Id.*; James Temple, *What Mexico's Planned Geoengineering Restrictions Mean for the Future of the Field*, MIT Tech. Rev. (Jan. 20, 2023), https://www.

Strong public opposition must be met with appropriate public engagement mechanisms.[430] We must ensure a just transition especially from the procedural facet of the right to a healthy environment. This procedural aspect calls for the inclusion of broader deliberative venues that ensure the consideration of local communities' concerns in decisions that will shape our common future.[431] Indeed, to truly achieve a just transition, local communities, Indigenous people,[432] and all citizens should be able to convey their concerns at appropriate times. Thus, SAI experimentation and deployment should aim to develop broad participative venues.[433] However, this must be contrasted with the possibility that public opinion might not align with geoengineering but against it, especially once it begins to move from experimentation to deployment.[434]

Given the state of development of solar geoengineering, the inclusion of wider mechanisms of public engagement should not only point to the decisionmaking stages, but also to the knowledge production itself.[435] In fact, at UNEA-6 in February 2024, most participant States "still indicated that they don't know enough about SRM—especially about the risks. As in 2019, many emphasized not only gaps in knowledge, but also the dominance of Northern ways of knowing."[436]

These questions resonate with the tense negotiations at UNEA aimed at addressing SRM.[437] In 2019, at UNEA-4, the Swiss delegation supported by 10 countries proposed a resolution to mandate UNEP to work on an assessment of the status of geoengineering technologies, focused on CDR and SRM.[438] However, this resolution was opposed by the United States and Saudi Arabia.[439] The opposition argued that the IPCC, rather than UNEP, was the appropriate venue to assess geoengineering technologies.[440] The United States also objected to the proposition from the European Union and Bolivia to include a precautionary approach in the preamble, as well as to include other forms of knowledge beyond science.[441] Thus, Switzerland withdrew the proposed resolution.[442]

Four years later, the countries met again during February 2024 for UNEA-6. This time, a new resolution was proposed by Guinea, Monaco, Senegal, and Switzerland.[443] The resolution suggested creation of an expert group to advise on the state of knowledge around geoengineering from a broad perspective.[444] In this scenario, the opposition was even more extended. On one side, there was the United States, with Saudi Arabia and Japan, arguing that the assessment of geoengineering technologies should be through the new Lighthouse Activity on Climate Intervention Research initiative of the WMO.[445] On the other side, there were many developing countries calling for a moratorium on SRM research and deployment, such as the whole African continent,[446] due to the "fear that, if passed, the resolution will possibly signal that SRM technologies are an acceptable practice."[447]

Another interesting case from which to distill lessons for open public dialogues is the Clean Development Mechanism Policy Dialogue under the UNFCCC, held in Durban 2011. We could draw from the recommendations of the clean development experience, such as to "improve accessibility and respond to stakeholders properly and professionally; [. . .] dissemination of accurate and accessible information and establish guidelines for adequate local consultation procedures to ensure local community stakeholders are promptly notified and consulted on proposed project activities."[448]

Moreover, regional agreements are essential to substantiate the procedural content of the right to a healthy envi-

technologyreview.com/2023/01/20/1067146/what-mexicos-planned-geoengineering-restrictions-mean-for-the-future-of-the-field/.

430. *E.g.*, Patrick Devine-Wright, *Public Engagement With Large-Scale Renewable Energy Technologies: Breaking the Cycle of NIMBYism*, 2 WIREs Climate Change 19, 24 (2011).

431. *See supra* Sections III.B and IV.C.2.

432. Kyle Powys Whyte, *Indigeneity in Geoengineering Discourses: Some Considerations*, *in* The Ethics of "Geoengineering" the Global Climate, *supra* note 9, at 60, 304.

433. National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 74 ("[M]erely providing opportunities for participation does not ensure that diverse voices will be heard and considered, [and thus] a number of scholars have highlighted the importance of 'recognitional justice.'"); Baum et al., *supra* note 11, at 10.

434. Bodansky, *supra* note 296, at 6.

435. *E.g.*, Reynolds, *supra* note 10, at 202:

> [I]nternational cooperation should be a priority, in order to capitalize on scientists' knowledge and skills worldwide, to foster socialization and build trust, and to avoid perceptions of rivalry or hostile activities. Moreover, international cooperation should not be mere sporadic collaboration and co-authorship but also include active recruitment, exchange programs, and capacity building in developing countries . . . .

Prantl et al., *supra* note 6, at 40; Foley et al., *supra* note 232, at 18-21.

436. Duncan McLaren & Olaf Corry, *Countries Failed to Agree First Steps on Solar Geoengineering at the UN. What Went Wrong?*, Legal Planet (Mar. 7, 2024), https://legal-planet.org/2024/03/07/countries-failed-to-agree-first-steps-on-geoengineering-what-went-wrong/.

437. *E.g.*, *Summary Report of the Sixth Session of the Open-Ended Committee of Permanent Representatives and the United Nations Environment Assembly: 19 February-1 March 2024*, Earth Negotiations Bull. (International Institute for Sustainable Development) (Mar. 4, 2024), https://enb.iisd.org/sites/default/files/2024-03/enb16176e.pdf [hereinafter 2024 Earth Negotiations Bull.] (At the opening session, many groups already expressed their concerns on SRM, with many different positions, such as the Local Authorities Major Group, and the NGO Major Group, the Scientific and Technological Community Major Group, or the Women Major Group.).

438. Switzerland, *Resolution for Consideration at the 4th United Nations Environment Assembly: Geoengineering and Its Governance* operative pt. 1 (Feb. 19, 2019).

439. McLaren & Corry, *supra* note 436; *Perspectives on the UNEA Resolution*, Harvard's Solar Geoeng'g Rsch. Program (Mar. 29, 2019), https://geoengineering.environment.harvard.edu/blog/perspectives-unea-resolution.

440. McLaren & Corry, *supra* note 436; *Summary of the Fourth Session of the United Nations Environment Assembly: 11-15 March 2019*, Earth Negotiations Bull. (International Institute for Sustainable Development) (Mar. 18, 2019) [hereinafter 2019 Earth Negotiations Bull.], https://enb.iisd.org/events/4th-meeting-oecpr-and-4th-session-unea/summary-report-11-15-march-2019.

441. McLaren & Corry, *supra* note 436; *Perspectives on the UNEA Resolution*, *supra* note 439.

442. 2019 Earth Negotiations Bull., *supra* note 440.

443. 2024 Earth Negotiations Bull., *supra* note 437.

444. McLaren & Corry, *supra* note 436.

445. See the last paragraph in Section I.A, *supra*.

446. McLaren & Corry, *supra* note 436; African Ministerial Conference on the Environment, *Report of the Meeting of the Nineteenth Session of the African Ministerial Conference on the Environment*, U.N. Doc. AMCEN/19/6, at 31 (Aug. 17, 2023).

447. 2024 Earth Negotiations Bull., *supra* note 437.

448. Atapattu, *supra* note 140, at 137; UNFCCC, *CDM Policy Dialogue: Report and Recommendations* (Oct. 12, 2012).

ronment, especially public engagement mechanisms. The Aarhus Convention[449] in Europe and the Escazú Agreement[450] in Latin America and the Caribbean[451] are useful sources of obligations for SAI and a human rights-based approach.[452] These agreements establish a set of rules to empower individuals and communities to participate in environmental decisionmaking processes.[453] These conventions focus on three key pillars: (1) access to information,[454] (2) public participation in decisionmaking,[455] and (3) access to justice in environmental matters.[456]

Aarhus and Escazú aim to ensure that the public, including individuals, environmental defenders, and their associations, have the rights to be informed about, and to participate in, environmental matters. These regional agreements, and especially the Escazú Agreement, given its recent ratification, could prove useful in enriching the framework shaping public engagement obligations under SAI research and deployment.

For instance, in the first part of the Escazú Agreement, the 24 signatory countries are obliged to "guarantee the right of every person to live in a healthy environment and any other universally-recognized human right related to the present Agreement."[457] The same States are also obliged to develop "open and inclusive participation in environmental decision-making processes based on domestic and international normative frameworks."[458] All of these could be applicable to the SAI case.

Still, there are many hurdles in the design of public engagement mechanisms and SAI governance.[459] Considering the magnitude of the challenge posed by climate change, as well as the global impact of SAI, there are questions about the scale and inclusiveness of public engagement mechanisms in an area pervaded by cutting-edge science and engineering, yet with substantial and broad benefits and risks borne by citizens in different ways around the world.[460] Regarding the scale, there is a need to strike a balance between meaningful deliberation and a representative percentage of the affected communities.[461] This paradox in deliberative democracies is accentuated under a global technology such as SAI, where the whole world is to endure the consequences of such endeavors.[462] Therefore, an appropriate public engagement mechanism would have to consider the whole world.

In this scenario, the role of an international governance body comes again into the discussion.[463] For instance, public engagement could be concentrated on a broader representative approach under the Vienna Convention and Montreal Protocol, where all 193 Member States of the U.N. participate through their appointed representatives.[464]

On the other hand, the inclusiveness of public engagement, especially under a human rights and just transition perspective, is essential.[465] The main critique of public engagement procedures regarding solar geoengineering is the lack of diversity "along geographical and cultural lines."[466] In this regard, a significant point of contention is the exclusion of perspectives from the Global South.[467] This will be a key challenge for engaging the public in developing SAI technologies, especially considering that the Global South population has a higher concern over suffering harm from climate change impacts and a better perception of technology as a potential solution.[468]

VI. Conclusion

> Whoever concerns himself with big technology, either to push it forward or to stop it, is gambling in human lives.
>
> —Freeman Dyson, *Disturbing the Universe* (1981)

Can we manage to deploy SAI under a human rights-based and a just transition approach? What is the pathway? Could it be through environmental principles, a clear international governance body, EIA constraints, and public engagement?

449. Reynolds, *supra* note 10, at 135-36.
450. Regional Agreement on Access to Information, Public Participation, and Justice in Environmental Matters in Latin America and the Caribbean, Mar. 4, 2018, LC/CNP10.9/5 [hereinafter Escazú Agreement].
451. Smita Narula, *Human Rights and Climate Change*, Climate Change Law: An Introduction 135, 157-58 (Karl S. Coplan et al. eds., Edward Elgar Publishing 2021).
452. *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 120-21.
453. Convention on Access to Information, Public Participation in Decision-Making, and Access to Justice in Environmental Matters, pmbl., June 25, 1998, ECE/CEP/43 [hereinafter Aarhus Convention]; Escazú Agreement, *supra* note 450, pmbl.
454. Aarhus Convention, *supra* note 453, arts. 4-5; Escazú Agreement, *supra* note 450, arts. 5-6.
455. Aarhus Convention, *supra* note 453, arts. 6-8; Escazú Agreement, *supra* note 450, art. 7.
456. Aarhus Convention, *supra* note 453, art. 9; Escazú Agreement, *supra* note 450, art. 8.
457. Escazú Agreement, *supra* note 450, art. 4.
458. *Id*. art. 7.
459. Flegal et al., *supra* note 3, at 405.
460. *E.g.*, *id*. at 404-06.
461. Eva Lövbrand et al., *A Democracy Paradox in Studies of Science and Technology*, 36 Sci. Tech. & Hum. Values 474, 483 (2011).
462. John Parkinson, *Legitimacy Problems in Deliberative Democracy*, 51 Pol. Stud. 180, 181 (2003); Frumhoff & Stephens, *supra* note 24, at 5 ("[G]overnments and civil society organizations well beyond the geographical reach of small-scale experiments are likely to see themselves as stakeholders in their design and implementation.").
463. *Political Legitimacy in Decisions About Experiments in Solar Radiation Management*, *supra* note 44, at 150 ("As 'participation' in an SRM experiment is a collective choice, not an individual one, researchers whose experiments have the legitimate approval of an appropriate institution will satisfy the demands of the Principle of Respect."); Allen Buchanan & Robert O. Keohane, *The Legitimacy of Global Governance Institutions*, 20 Ethics & Int'l Affs. 405, 417-29 (2006). *See supra* Section V.C.2.
464. National Academies of Sciences, Engineering, and Medicine, *supra* note 7, at 187 ("[E]very effort should be made to ensure that sound public engagement practices are applied when SG research governance is taken up by international institutions and that engagement activities are expanded when possible and appropriate.").
465. *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 122-23.
466. Flegal et al., *supra* note 3, at 406; Wylie Carr & Christopher J. Preston, *Skewed Vulnerabilities and Moral Corruption in Global Perspectives on Climate Engineering*, 26 Env't Values 757, 758 (2017).
467. Winickoff et al., *supra* note 301, at 627-29; Flegal et al., *supra* note 3, at 404; Baum et al., *supra* note 11, at 1-2.
468. Baum et al., *supra* note 11, at 9; *but see* Carr & Preston, *supra* note 466, at 772-73 (arguing that "focusing on providing relief from physical climate change impacts could obscure other, more complicated ways in which climate engineering could actually make certain vulnerable populations worse off").

SAI technologies are still nascent. Given their significant impacts, the scientific community is calling for regulatory frameworks that allow sufficient experimentation. Indeed, SAI could help prevent temperature peaks expected to be produced by climate change in the coming decades from the mid-2020s through the end of the century. SAI would buy time to develop and implement robust adaptation and mitigation measures.

Nonetheless, there are many concerns surrounding SAI development, such as how to strike a balance between scientific experimentation, tolerable socio-environmental risks, and human rights for a just transition. I argued that the global recognition of a human right to a healthy environment is the missing link to build a normative framework and include a human rights perspective in climate change governance. This approach should also be complemented by the vibrant just transition framework linked to environmental, energy, and climate justice arenas.

Accordingly, I explored a bridge to channel the many concerns on research and deployment of SAI from an institutional perspective. For this, I identified potential human rights and just transition mandates for SAI and proposed mechanisms to harmonize this approach. However, the limitations of this approach are many. For instance, a human rights framework "has far greater difficulty in providing practical guidance for policymakers. In other words, the human rights framework may be much better at diagnosis than at treatment."[469]

This Article recounts and addresses some of the key legal issues identified by the literature from scholars, practitioners, and international organizations. Given its contentious nature, numerous aspects of these issues will continue to be the subject of further research. As highlighted throughout, it is of critical importance to explore the potential impacts of SAI through the human right to a healthy environment and a just transition framework to face the near-term impacts without accelerating a humanitarian and climate catastrophe.

469. *A Human Rights Framework for Climate Engineering: A Response to the Limits of Cost-Benefit Analysis*, *supra* note 20, at 128.