3

International Law

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3.1. INTRODUCTION

Once the risks posed by climate change became widely known in the late 1980s, the policies needed to reduce these risks were immediately recognized as a matter of international law.[1] Although activities that emit greenhouse gases (GHG) benefit the emitters themselves, the accumulation of atmospheric GHGs will harm people and the environment across borders and generations. Limiting these emissions (through abatement, also called mitigation) would cost the country or other actor that took such steps, yet the benefits would be shared by the entire world, accruing especially to the future. Those who are willing to limit their emissions need assurance that others will also do the same, and not merely "free ride" on others' efforts. Some mechanism, often a legal one, is needed for this assurance of commitments and minimization of free riding. In addition to emissions abatement, other international actions – such as the adaptation of societies and ecosystems to a changed climate, research coordination, information sharing, and knowledge transfer – are necessary to reduce climate change risks, and they also are furthered by international legal mechanisms to ensure their implementation. Moreover, there are other important international legal issues, such as interactions between emissions abatement and trade law. Despite this early recognition and subsequent efforts, emissions abatement and adaptation remain insufficient and disappointing more than a quarter century later. It is clear that reducing climate change risks is a very difficult problem, arguably the most difficult one that humanity currently faces.

Some scientists and others who are concerned about climate change are increasingly considering climate engineering – intentional, large-scale interventions in natural systems to prevent or counter climate change. As described in more detail in Chapter 2 of this volume, these proposals come

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in two primary categories: carbon dioxide removal (CDR) and solar radiation management (SRM).[2] Like climate change, climate engineering was quickly recognized by scholars as a matter of international relations and cooperation, and specifically one of international environmental law.[3] The most important aspect of climate engineering for the purpose of international law is that its large-scale outdoors research and implementation would affect the environment across borders and in areas beyond national jurisdictions. Other issues of international law and cooperation more generally arise as well. For example, the climate change regime gives wealthy countries "differentiated responsibilities," including an obligation to share knowledge and technology – perhaps including that of climate engineering – with poorer developing countries. Likewise, climate engineering research would presumably be more efficient and legitimate through international coordination.

Aspects of climate change mitigation and climate engineering present problem structures that are, in various ways, both similar and distinct. They are public goods – something whose enjoyment is nonexcludable and nonrivalrous – with large spatial and temporal dimensions.[4] More specifically, CDR climate engineering resembles emissions abatement, in which individual actors choose whether to take immediate and costly actions whose climatic benefits would be widely dispersed and delayed in time. These actions may offer net benefits for the world, but they usually pose a net loss for the provider.[5] The primary challenges with these "aggregate effort global public goods" are getting the actors to provide the public good, assuring potential providers that others will also fulfill their promises, and limiting free riding. Together, these challenges are called a collective action problem. In contrast, some SRM methods presently appear to be so inexpensive and rapidly acting that, even though their expected beneficial effects would still be widely dispersed, the benefits that would immediately accrue to their provider could outweigh their direct financial costs.[6] The primary challenges with such a "single best effort global public good" are preventing the actors who have the capacity to provide it from providing it excessively or prematurely, and coordinating their efforts. These distinct problem structures mean that the implications of existing international law and the probable development of new law will vary, mainly between emissions abatement and CDR in one column and SRM in the other.

This chapter provides an overview of the existing international law of climate engineering. Although there are presently no international instruments that are legally binding, in force, and specific to climate engineering, numerous components of international law are relevant and have implications of varying clarity for climate engineering. Furthermore, some international legal instruments are specific to climate engineering, but are nonbinding or are not yet in force. The scope of the discussion here is limited to the implementation or large-scale outdoor research of climate engineering in a manner where international law might apply. For the most part, this would arise when the climate engineering activity would pose a significant risk of environmental harm that would either be transboundary or would occur in an area beyond national jurisdiction. Other aspects of international law are pertinent to climate engineering even in the absence of transboundary environmental risk, such as the prevention of international conflicts; the creation of international institutions for deliberation; legally binding commitments or hortatory calls for states to cooperate in research, to share knowledge, and to transfer technology; the expression of states' priorities; impacts on human rights; and intellectual property standards.

Three caveats are in order. First, this exploration is inherently speculative. Climate engineering proposals remain at early stages. How and whether these proposals will develop into real, effective, and socially acceptable technological means to reduce climate risks are highly uncertain. The best that can be done is to extrapolate from current knowledge and trends in order to generate reasonable scenarios, while simultaneously remaining open to an array of other potential yet seemingly less likely futures. This balance of focus between the probable and possible is obviously a subjective practice.

Second, climate engineering – like many human endeavors – would pose both potential benefits and risks. It is essential to bear in mind that climate engineering techniques are not being considered and researched in isolation, but in response to anthropogenic climate change. That phenomenon is poised to cause enormous harms to humans, nonhuman species, and ecosystems, particularly those that are already highly vulnerable. When quantified in monetary terms, and discounted for the future, climate change is expected to do global harm in the order of tens of trillions of US dollars.[7] The irreversible loss of species and ecosystems, and the suffering of the poor, are difficult to capture in such terms. Because the leading conventional means to reduce these risks – adaptation and emissions abatement – are each expensive, then an economically optimal climate policy where these means are adopted until their marginal costs equal their marginal benefit would still result in significant harm from climate change. Moreover, optimal policies are unlikely to be implemented due to abatement's collective action problem: the need for large international transfers of financial resources to achieve genuinely effective adaptation, and the ability of economic interests that would be harmed by optimal policies to block action.

Some climate engineering proposals presently appear to be able to reduce climate risks, and in some ways that abatement and adaptation cannot. Yet climate engineering presents physical and social risks of its own. Most importantly for the purposes of this chapter, both climate engineering and the climate change (or global warming, or elevated atmospheric GHG concentrations) that it may reduce satisfy the definition of "pollution," "adverse effects," or "damage" that multilateral environmental agreements strive to minimize. This definitional coverage presents a challenging tension between climate change and climate engineering. Because of this, in some circumstances the net expected effects of climate change and climate engineering should collectively be taken into account. How this is done, which factors are considered, the relative weights given to these factors, and the thresholds of harm's magnitude and probability will depend on the particular legal environment as well as on the actual and anticipated impacts of the phenomena at hand. Given the high levels of uncertainty concerning climate engineering's effects as well as the limitations of indoor research and modeling, any such balancing would need to be a dynamic process that is capable of responding to new information.[8]

Finally, this chapter is an exercise in the interpretation of international law, relying on the text of explicit agreements, widely accepted formulations of custom and principles, and – where helpful – on the preparatory and other supporting documents that can provide insight into states' intention behind and interpretation of international law. In reality, international law is not so clear-cut, but instead operates in a political context of state and nonstate actors that have diverse interests and levels of power. These actors have therefore interpreted, applied, and enforced international law inconsistently, and will continue to so.

The next section briefly introduces international law. Readers who are already familiar with this topic may skip this discussion. From there, the chapter reviews existing international law that is applicable to climate engineering, organized in sections concerning multilateral environmental agreements, nonbinding environmental agreements, custom, principles of international environmental law, and related domains other than the environment. Emerging norms and codes of conduct, which may be highly relevant to climate change, are examined next. The chapter closes with a discussion of the scholarship of the international law of climate engineering, including a brief review of it, an attempt to identify the challenges that it poses for legal scholars, and possible future directions.

3.2. INTERNATIONAL LAW

Under international law, countries, often called states or nations, are sovereign. Here, words such as "state" are often anthropomorphized and meant to imply the governing institutions that exercise control over a territory and a group of people. Sovereignty means that countries are free to manage their internal affairs and to carry out relations with other sovereign countries as they see fit, free from unwanted external interference. Their territories are defined and mutually exclusive. All states are equally sovereign, at least legally. There are no institutions that can exert legally binding authority over sovereign states without the states' consent.[9] Of particular importance for this chapter is that sovereignty generally includes the right for countries to exploit their own natural resources as they deem appropriate, except when this has negative extraterritorial impacts.[10] Notably, some areas – such as the high seas, Antarctica, and outer space – are not within the jurisdiction of sovereign countries.[11]

Reality is not so distinct Nationals of one country travel to others. Some territories remain legally dependent on distant countries, sometimes in a quasi-colonial manner. Other areas are claimed by multiple states. A government might not be able to exert its authority effectively over certain regions or populations within its borders. Some regions might not have any formal or legal governing institutions. Activities in one state's territory or under its control sometimes harm the environment of another. State and nonstate actors regularly try to influence and interfere in the internal and external affairs of other states, not always peacefully. Some countries are more powerful than others and are consequently able to influence other states, calling into question the theoretical equality of legal sovereignty.

When states interact, they face problems that are analogous to those that individuals in society face. Both countries and individuals benefit by having expectations regarding others' behavior, and therefore make explicit and implicit mutual promises. In the international arena, these promises have coalesced into something that resembles law. In fact, through this, states collectively try to fill the same sorts of functions internationally as national law does domestically: prevent and resolve conflicts, provide beneficial public goods, reduce negative externalities, promote positive externalities, enforce contracts and property rights, and encourage behavior consistent with widely agreed-upon normative principles. The central and very important difference is that people and domestic institutions are subject to binding national law that is enforced through the threat of socially sanctioned appropriation of property, freedom, and sometimes even life, whereas sovereign countries are not. This lack of centralized or hierarchical enforcement gives international law certain distinct characteristics.

International law is typically described as coming from three sources. First, states can make explicit agreements with one another in which they promise to do, to not do, to try to do, or to try not to do specific activities. These treaties, agreements, or conventions resemble contracts, and are considered legally binding (inasmuch as international law is legally binding) on those countries – often called Parties – that ratify them. Prior to ratification, states might sign a treaty, signaling their intention to ratify. In the meantime, such non-Party signatories may not act contrary to the agreement's core objective, but are not legally bound by it.[12] The vast majority of treaties are between only two countries, but some count many more as Parties. Parties generally may withdraw from treaties.[13] Some treaties establish institutions, such as regular meetings of Parties, secretariats, and scientific advisory bodies, that perform various intergovernmental functions. Second, over the course of centuries of interaction, countries have developed customary behavior among them. Once such customary behavior is widely practiced and there is evidence that this conduct arose from a sense of legal obligation, it then is considered legally binding. Customary international law is not codified, although some authoritative institutions regularly suggest language. States may explicitly object, and be exempt from, particular tenets of customary international law. Third, general principles guide the interpretation and development of international law. These are not legally binding in themselves, but must be operationalized in a treaty or in custom. Beyond these three sources, others such as nonbinding agreements among countries, rulings of international tribunals and domestic courts, statements of intergovernmental organizations, and scholarly writing can influence international law.

Despite the absence of a centralized or hierarchical power, international law can be and is enforced.[14] First, states can sometimes enforce international law through reciprocation, in which violators are punished by others' equivalent violations, which are often legally sanctioned.[15] This tit-for-tat can be effective when the reciprocal violation is beneficial for the punisher, at least in the short term, such as in trade agreements. Second, states can punish violators through retaliation, either within the issue area at hand or, more often, in another one. However, retaliation, such as economic sanctions or military action, is costly to the punisher. Retaliation is thus itself often a public good and will consequently be undersupplied due to collective action problems. Third, violators will suffer reputational damage, and will find it subsequently more difficult to reap the benefits of international cooperation. Notably, states can experience reputational damage also for acting contrary to nonbinding international law, or even to unwritten expectations, blurring the definition of "binding." Finally, ex post renegotiation – more cynically called bribes – can be an additional mechanism to reduce noncompliance.[16] Here, other countries offer to pay the violator either directly or (more often) indirectly to cease the breach, sometimes under the guise of assistance with compliance. This exchange can amount to de facto renegotiation of the agreement, and presents the hazard of strategic future noncompliance to extract more payments.

Together, these four enforcement mechanisms are of limited effectiveness. For this reason, much of international law emphasizes preventing violations and conflicts in the first place. Furthermore, as noted in the introductory section, enforcement occurs in a political context of states with diverse interests and levels of power. Not surprisingly, actual enforcement depends on the identities of the violator and the victim.

Just as the reality of countries and their sovereignty is less clear than legal theory implies, so too are the external and internal boundaries of international law unclear. In recent decades there has been growing recognition of diverse arrangements by authoritative state, substate, intergovernmental, and nonstate institutions that seek to intentionally and explicitly influence various actors' actions. Such "transnational law" or "global governance" has advantages over more narrowly defined international law in some circumstances, such as when the regulated actors operate in transboundary manners, when the conditions are highly dynamic, and when political leaders have insufficient incentives or opportunities to adopt national or international policy within the issue area.

International law typically governs the actions of states, not of individual people, corporations, or other nonstate entities. Although there are a few exceptions, such as international criminal law, for the most part nonstate actors are governed indirectly. That is, countries might ratify a treaty in which they promise to require, prohibit, encourage, or regulate certain behaviors from nonstate actors that are within their jurisdiction or under their control. The state often implements international law through domestic law and administrative policy. If it does so in a manner consistent with the standards of international law, then it generally remains in compliance even when a private actor within its jurisdiction or under its control acts in a way contrary to international law.

Finally, most of climate engineering's legal issues relate to environmental concerns, such as avoiding climate change, reducing pollution, preventing transboundary harm, and conducting environmental impact assessments. International environmental law is thus central. Notably, international environmental law is generally not oriented toward protecting ecosystems and Earth systems for their own sake. Instead, "almost all justifications for international environmental protection are predominantly and in some sense anthropocentric."[17]

3.3. LEGALLY BINDING MULTILATERAL ENVIRONMENTAL AGREEMENTS

Multilateral environmental agreements contain explicit promises that states have made to each other regarding the environment. This section reviews legally binding ones, organized in subsections for those focused on the

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atmosphere, on oceans, on procedural duties, and on other topics. Section 3.5 discusses nonbinding environmental agreements.

Here, and in the other sections that review international law, when an agreement invokes a tenet of customary international law or a general principle of international environmental law, it will be briefly mentioned along with any relevant details, but discussed in more depth in the appropriate later section.

3.3.1. *Atmospheric Agreements*

Climate change is foremost an atmospheric phenomenon. Its cause is elevated atmospheric concentrations of GHGs, and the changes manifest primarily and most immediately in the atmosphere. Climate engineering would operate either directly in the atmosphere, by making it more reflective, by withdrawing carbon dioxide from it, or by allowing more heat to escape, or indirectly, by making the surface below it more reflective or by reducing the amount of solar radiation that it receives.

International law does not clearly define the atmosphere and responsibility for its quality. A state has sovereign rights over its airspace, which is the volume above its territory extending upwards to the undefined border with outer space. However, the air that constitutes the atmosphere moves and mixes, including across national boundaries and through airspaces. Pollutants consequently travel, and these movements are often addressed through various bilateral and regional agreements. Some atmospheric pollutants, notably ozone-depleting substances and GHGs, have global effects and therefore call for a global response. Proposals for a comprehensive "Law of the Atmosphere" have surfaced occasionally – especially when the scientific understanding concerning climate change risks first emerged – but these have not encountered warm receptions.[18] The International Law Commission (ILC) of the UN is presently developing draft guidelines, examined in more detail below, on the protection of the atmosphere that reflect current international environmental law, although the guidelines' scope excludes issues that existing international law already addresses.[19] The present draft of these guidelines defines the atmosphere as "the envelope of gases surrounding the Earth" and states that "the protection of the atmosphere from atmospheric pollution and atmospheric degradation is a pressing concern of the international community as a whole."[20]

3.3.1.1. UN Framework Convention on Climate Change

The UN Framework Convention on Climate Change (UNFCCC) is the central international legal instrument for multilaterally coordinated efforts to limit climate change and its impacts. As a framework, it is a general agreement with limited commitments, and sets out expectations for subsequent, more detailed protocols. All globally recognized countries, as the phrase is typically understood, are Parties to the UNFCCC.[21] Its objective is the

> stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.[22]

Because the excess quantity of the leading anthropogenic GHG – carbon dioxide – is naturally withdrawn from the atmosphere at very slow rates, it is essentially a cumulative pollutant. Genuine stabilization of its concentration implies something close to net zero emissions. This stabilized concentration should prevent "dangerous anthropogenic interference with the climate system," which is undefined in the UNFCCC itself. However, in a subsequent agreement under the UNFCCC – the Paris Agreement, discussed below – countries agreed that global average temperatures should stay well below 2°C above preindustrial levels, implying a stabilized carbon dioxide concentration of less than 460 parts per million.[23] The current emissions trajectory, while uncertain, implies that the atmospheric carbon dioxide concentration will cross this threshold around the year 2035 under "business-as-usual" assumptions."[24] The second half of the objective indicates that this stabilization must be done somewhat rapidly. This goal rules out a large overshoot of the carbon dioxide concentration limit followed by its drawdown through CDR. Together, a literal reading of the objective under present circumstances and forecast trajectories calls for the rapid development of and heavy reliance upon CDR.[25] Notably, of the four scenarios (called "Representative concentration pathways") currently used by the Intergovernmental Panel on Climate Change (IPCC), the most optimistic two, which are forecast to prevent 2°C warming and to delay it until the twenty-second century, respectively, each assume large quantities of CDR. In these projections, the CDR would be carried out through bioenergy with carbon capture and storage (BECCS). At the scales envisioned, this would constitute climate engineering. However, this approach would compete with agriculture for arable land, increasing food prices and running contrary to the UNFCCC's objective "that food production is not threatened." It would also degrade preserved and relatively natural land, reducing biodiversity.

The relationship between the UNFCCC's objective and SRM is unclear. These climate engineering techniques would not directly affect greenhouse gas concentrations, although they would have indirect effects. Moreover, SRM itself could be seen as "dangerous anthropogenic interference with the climate system," ex ante due to expected risks, or ex post due to actual negative impacts. On the other hand, certain SRM methods appear to be rapidly effective at reducing the most dangerous aspects of climate change. Moreover, compared to emissions abatement, SRM is more likely to be implemented at a level that is nearer to the optimum, due to their different problem structures.[26] Therefore, a hope is that SRM could be used to slow down or prevent most climate change impacts – including those on ecosystems, food production, and economic development, which are all emphasized in the objective – while society transitions to zero net GHG emissions. (SRM's large uncertainties and its inability to impede ocean acidification, are important dampers on this hope.) Notably, the UNFCCC does not prohibit or exclude any means to reduce climate risks.

The UNFCCC invokes several principles of international environmental law and tenets of customary international law. The former include the environment as a common concern of humankind, common but differentiated responsibilities, general equity, intergenerational equity, sustainable development, and precaution.[27] The latter tenets are the sovereign right to exploit domestic natural resources and the responsibility to prevent transboundary harm.[28] The Convention is also anthropocentrically and economically oriented. The anthropocentricism is apparent both in the objective, in which two of the three criteria for the speed of GHG stabilization are for the sake of the human race, and in its first principle: "The Parties should protect the climate system for the benefit of present and future generations of humankind."[29] That is, the UNFCCC's objective and commitments are to be pursued *not* with the goal of a planet or atmosphere that is less impacted by human activities, but instead with one that prioritizes humans' well-being primarily and ecosystems secondarily. The importance of economic activity, particularly economic growth in the developing countries, is clear throughout the UNFCCC. This is seen both in its firm commitments (e.g., "Parties … shall … employ appropriate methods … with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change") and in its soft ones (e.g., "Parties should … tak[e] into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost").[30] Because some SRM methods presently appear to have very low financial costs of implementation, these passages could imply that these lower-cost means to reduce climate risks should be given some priority within a wider portfolio of policies. Again, such an approach should consider SRM's own risks to people and the environment.

Although the UNFCCC's commitments mainly focus on gathering and sharing information and on developing general national plans, four themes found therein have implications for climate engineering. First, and most specifically, Parties are committed to minimizing a range of adverse effects – on the economy, public health, and the environment – in the activities that they undertake to reduce climate change risks.[31] Therefore, they would need to practice due diligence, such as by carrying out prior impact assessments, in their climate engineering programs.[32]

Second, Parties are to achieve the Convention's objective of stabilizing GHG concentrations through both emissions abatement and the conservation and enhancement of sinks and reservoirs.[33] For example, "All Parties … shall … promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems."[34] All CDR methods would utilize sinks ("any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere") and some also rely on reservoirs ("a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored").[35] This indicates that, at least in theory, all UNFCCC Parties have implicitly agreed to promote and cooperate in CDR implementation, in ways appropriate and consistent with the other terms of the Convention.

The third relevant set of Parties' commitments concerns research and technology. Several commitments in the UNFCCC call for Parties to undertake research, to cooperate therein, and to share the results. For example,

> All Parties … shall … Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies.[36]

The term "various response strategies" is not defined but presumably could include climate engineering. Other commitments concern the development and diffusion of technologies, especially those that would "control, reduce or prevent anthropogenic emissions of greenhouse gases," which appears to include CDR techniques.[37] To this end, in 2010 the UNFCCC Conference of Parties (COP) created a Technology Mechanism, including a Technology Executive Committee, to implement the UNFCCC's commitments related to the development and transfer of technology.[38]

Adapting to a changing climate is the fourth and final set of UNFCCC commitments that might apply to climate engineering. Several commitments and one principle explicitly call for adaptation, for example through the development and implementation of national adaptation plans.[39] Others, such as those concerning "various response strategies" and technology transfer, are implicitly adaptive. Adaptation is undefined both in the UNFCCC itself as well as by the decisions of its COPs. The Convention's website and other documents often use a definition developed by the IPCC: "Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change."[40] SRM climate engineering could fall within this unofficial definition's latter sentence, in that it would be a change in practices to moderate potential climate damages.

The Kyoto Protocol of 1997 is a protocol to the UNFCCC that is in force, having been ratified by almost all UNFCCC Parties. (The USA did not ratify, and Canada ratified and later withdrew.) It is dedicated to specific GHG emissions abatement targets, especially for industrialized countries. It thus has little implication for SRM, save for further commitments by industrialized country Parties to implement policies to inter alia research, promote, develop, and transfer "environmentally sound technologies," and to cooperate in research to reduce uncertainties concerning "various response strategies."[41] In contrast, CDR technologies are highly relevant. Explicitly, the industrialized country Parties' policies cited above are, among other things, to protect and enhance sinks and reservoirs and to research, promote, develop, and transfer "carbon dioxide sequestration technologies."[42] Furthermore, the industrialized countries are able to satisfy their GHG emissions targets by, among other methods, afforestation, which is sometimes considered a CDR method.[43] The Parties may choose to permit other activities involving agricultural soils, land use changes, and forestry to contribute to achieving industrialized Parties' targets.[44] This could include biochar, for example. However, the Kyoto Protocol's first round of targets ended in 2012; an amendment providing for a second round that would end in 2020 has been approved but is not yet in force.[45] CDR is present implicitly in other commitments toward abatement. For example, industrialized countries are to implement systems to estimate removal of all GHGs by sinks, including through the enhancement of sinks.[46] Furthermore, the Kyoto Protocol established several flexibility mechanisms in order for the industrialized country Parties to meet their emissions targets more efficiently. The Protocol leaves the criteria for these mechanisms somewhat general.[47] The scope for CDR within the COP's guidelines for flexibility mechanisms, such as joint implementation and the clean development mechanism, is presently limited to forestry activities such as afforestation, but could be broadened.

At the 2015 COP in Paris, international negotiators approved the second legally binding agreement under the UNFCCC, and it entered into force the following year. Compared with the Kyoto Protocol, the Paris Agreement offers a fundamentally different approach to emissions abatement. Here, Parties' first aim is to keep global warming "well below 2°C," and they are "to pursue efforts to limit the temperature increase to 1.5°C."[48] Limiting expected warming to 2°C will require net GHG emissions to peak almost immediately, to be zero by sometime soon after 2050, and to be negative thereafter.[49] Parties are to do this not only by abatement but also through "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century," indicating the growing importance of CDR.[50] All Parties are to submit their own nationally determined contributions toward the Agreement's abatement aim. Almost all Paris Agreement Parties have done so already, and none of these explicitly includes carbon dioxide removal.[51] The Paris Agreement replaces the Kyoto Protocol's various flexibility mechanisms with a new approach to voluntary cooperation in implementing Parties' contributions, including through "internationally transferred mitigation outcomes."[52] The UNFCCC institutions will need to further clarify which activities, including enhancements of sinks and reservoirs, qualify toward a Party's own contribution and those of others via internationally transferred mitigation outcomes. This process will presumably build upon their analogous work for the Kyoto Protocol, and could address a growing number of activities, including some that fall within common definitions of CDR. Such determinations will be simpler for the more contained CDR techniques, such as direct air capture and BECCS, where the quantity of removed GHG can be monitored, reported, and verified fairly well. In contrast, the amount of captured carbon dioxide through ocean fertilization would be very difficult to ascertain reliably.[53] In addition, the Paris Agreement places much more importance on adaptation than did the UNFCCC and the Kyoto Protocol. In the Agreement's second of two aims, adaptation is now an explicit goal on par with abatement.[54] It is to be pursued in "a manner that does not threaten food production" and "with a view to contributing to sustainable development."[55] If SRM were to be considered a component of adaptation, then Parties to the Agreement could include it as part of their obligatory adaptation plans and it would constitute part of the global stocktaking, which is to occur every five years.[56] Such an inclusion could be justified by the growing unlikelihood of keeping global warming to within 1.5°C or 2°C. Furthermore, Parties' adaptive SRM activities should satisfy a number of desiderata set out by the article: They should be participatory and transparent, take into consideration vulnerable groups, be based upon the best available science, and be integrated with socioeconomic and environmental policies and actions.[57]

Finally, somewhat independent of the precise wording of the objective, principles, and commitments of the UNFCCC and its protocols, its affiliated institutions are a logical home for some form of climate engineering assessment and governance, broadly defined. The UNFCCC is clearly the central international legal instrument to reduce climate change risks. It also has global participation and robust institutions, including annual COPs, a Secretariat, a Subsidiary Body for Scientific and Technological Advice, and an explicit – albeit weak – dispute settlement procedure.[58] This is not to assert that it should be the site of the international regulation of all climate engineering.[59] Instead, the UNFCCC institutions might eventually be able to offer a forum for international discussion of how various climate engineering methods could further the objectives of the UNFCCC and its related agreements. In addition, the elaboration of the rules and guidelines for the UNFCCC regime's reporting standards, the Kyoto Protocol's commitments and flexible mechanisms, and the Paris Agreement's voluntary cooperation could situate various CDR techniques within or outside the portfolio of internationally recognized emissions abatement methods.

3.3.1.2. Vienna Convention for the Protection of the Ozone Layer

Prior to the emergence of climate change as an international scientific, political, and legal issue, the destruction of stratospheric ozone by the emission of certain anthropogenic substances was the preeminent known environmental problem of the global atmosphere. This loss of stratospheric ozone increases the amount of ultraviolet radiation at the Earth's surface, especially at higher latitudes, posing risks to humans and the environment. Fortunately, the general alignment of state interests, the large net benefits of ending emissions of ozone-depleting substances, and the availability of substitute chemicals enabled the international community to respond rapidly and effectively. The Vienna Convention for the Protection of the Ozone Layer of 1985 is the central framework convention, has limited commitments, and enjoys universal participation. It is furthered by its Montreal Protocol of 1987, in which its 197 Parties commit to phase out specific ozone-depleting substances. The agreements are supported by a standing secretariat and other dedicated institutions at the UN Environment Programme, regular COPs, a robust compliance mechanism, three Assessment Panels that provide scientific and technical input, and procedures for amending the agreements and updating other policies.

Stratospheric ozone and climate engineering are potentially related via general and specific mechanisms. The general relationship is that elevated atmospheric GHG concentrations and climate change will affect stratospheric ozone concentrations as well as ground-level ultraviolet radiation in complex ways. However, the sign and magnitude of the net effect remain uncertain, and they will certainly vary by latitude.[60] Regardless, CDR climate engineering techniques, if effective, would lessen all of these effects, whereas SRM would do so for only some. One specific issue is that sulfate particles, the leading candidate for stratospheric aerosol injection SRM, might deplete stratospheric ozone. However, the sulfate aerosol's presence might partially or fully counteract this effect by blocking some incoming ultraviolet radiation.[61] Therefore, the net effect of sulfate stratospheric aerosol injection is also unclear. Notably, the potential impact of sulfate aerosols on stratospheric ozone is a leading area of SRM research, through both the exploration of alternative aerosol materials and a proposed field experiment.[62] A second specific issue is that cirrus clouds might naturally contribute to stratospheric ozone depletion yet might block the rise of water vapor, which in the stratosphere acts as both a GHG and an ozone destroyer.[63] Cirrus cloud thinning could thus affect stratospheric ozone, although again the net impact is uncertain.

The implications of the Vienna Convention and its Montreal Protocol for climate engineering implementation are therefore unclear and dependent upon the outcome of future research. If stratospheric aerosol injection (or some other form of climate engineering) were to cause or were likely to cause "adverse effects resulting from modification or likely modification of the ozone layer," then Parties would be committed to adopt policies to control, limit, reduce, or prevent these activities.[64] Note that "significant" implies a relatively moderate threshold for the magnitude of harm, greater than "detectable" but not necessarily "serious" or "substantial." The Parties to the Montreal Protocol could then choose to add the ozone-depleting substance to the list of controlled substances.[65] Because they are to "take appropriate measures … to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer," the Parties' decision should balance the protective and adverse effects that occur through impacts on the ozone layer.[66] However, given that sulfate aerosols are already produced, albeit unintentionally, through industrial processes (especially coal combustion) in the lower atmosphere at an annual rate roughly ten times that which would be needed to offset global warming, in this case the Parties would need to incorporate some qualifier regarding the location of emissions.[67]

In contrast to its approach to climate engineering implementation, the Vienna Convention is somewhat clearer regarding climate engineering research. Its Parties commit to

> "[c]o-operate by means of systematic observations, research and information exchange in order to better understand and assess the effects of human activities on the ozone layer" and "to initiate and co-operate in … research and scientific assessment on: The physical and chemical processes that may affect the ozone layer; … [c]limatic effects deriving from any modifications of the ozone layer; … [and] [s]ubstances, practices, processes and activities that may affect the ozone layer, and their cumulative effects."[68]

Climate engineering in general, as well as cirrus cloud thinning and stratospheric sulfate aerosols specifically, are activities and/or substances that may affect the ozone layer. Therefore, Parties implicitly committed themselves in this article to researching potential impacts on stratospheric ozone from climate engineering activities. The obligation to conduct research, which the Montreal Protocol reiterates and expands, also includes a corollary duty to transfer technology.[69]

3.3.1.3. Convention on Long-Range Transboundary Air Pollution

The third and final multilateral atmospheric agreement that is relevant to climate engineering is the Convention on Long-Range Transboundary Air Pollution (CLRTAP) of 1979. Like the UNFCCC and the Vienna Ozone Convention, it is a framework convention with operationalizing protocols. In contrast, though, CLRTAP is a regional agreement, developed under the UN Economic Commission for Europe (UNECE), addressing the problem of acid rain due to the transboundary movement of certain pollutants. Its 51 Parties include all fully industrialized countries and most emerging economies of North America, Europe, and central Asia. As in other framework conventions, Parties to CLRTAP itself have only general and often softly worded commitments to, for example, monitor, exchange information, consult with one another, and develop air quality management systems.[70] CLRTAP's principles use obligatory language, in which its Parties inter alia "shall endeavour to limit and, as far as possible, gradually reduce and prevent air pollution."[71] Here, the definition of air pollution – which is seen elsewhere in

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international environmental law – includes GHGs, perhaps global warming, and any harmful substances used for atmospheric climate engineering:

> "Air Pollution" means the introduction by man, directly or indirectly, of substances or energy into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment.[72]

Note that, here, deleterious effects must reach a certain threshold of magnitude, and must have actually already occurred, which is or will soon be the case with GHGs and global warming. This definition highlights the recurring tension in international environmental law between climate change and climate engineering. Clearly, CLRTAP and its current Protocols – like current legally binding international law – do not address climate engineering per se. However, given this definition of pollution, a new Protocol to govern climate engineering, especially those methods that would operate by introducing substances into the air, would be within the scope of CLRTAP. Finally, this agreement has institutional support from the UNECE, its own standing bodies, a noncompliance procedure, ongoing scientific support, and the capacity to be amended through protocols.

The legal implications of CLRTAP for the implementation of climate engineering, and especially of atmospheric SRM and cirrus cloud-seeding methods, are somewhat similar to those of the Vienna Ozone Convention. At the very least, source Parties must report their emissions of acid rain precursors – which include sulfates, presently the leading candidate substance for stratospheric aerosol injection SRM – and consult with other Parties "which are actually affected by or exposed to a significant risk of long-range transboundary air pollution."[73] CLRTAP also commits its Parties to the research and development of, among other things, technologies to reduce air pollution and "economic, social and environmental assessment[s] of alternative measures for attaining environmental objectives including the reduction of long-range transboundary air pollution."[74] Given that GHGs and perhaps also global warming are air pollution according to the CLRTAP definition, this provision implies a commitment to research, develop, and assess climate engineering methods that have a potential to reduce the deleterious effects of GHGs and/or global warming. If a climate engineering activity were known to actually cause deleterious effects, then CLRTAP Parties would be obligated to, among other things, endeavor to limit and to gradually reduce and prevent it, as far as possible. If these activities also reduced the deleterious effects of GHGs and/or global warming, then the Parties (likely operating through the Convention's Executive Body and Implementation Committee) should also to take this into account as appropriate. Furthermore, if particular climate engineering techniques were believed to offer "the best available technology which is economically feasible and low- and non-waste" to reduce harm from GHGs and/or global warming, then Parties arguably would be committed to include them as part of their air quality management systems that are designed to combat air pollution, though it is unclear whether the Parties would have to actually carry them out.[75]

The goals and commitments of CLRTAP are furthered by eight protocols, most of which establish emission limits for various long-range air pollutants. All protocols are in force, with differing constellations of participating states.[76] Three of these – the 1985 Helsinki Protocol, the 1994 Oslo Protocol, and the 1999 Gothenburg Protocol – include sulfate emissions. Research on stratospheric sulfate aerosol injection appears to be favored under the Oslo Protocol, wherein Parties commit to "encourage research, development, monitoring and cooperation related to … [t]he understanding of the wider effects of sulfur emissions on human health [and] the environment."[77] One reading of this language is that it is a commitment to improve the understanding of the potential health and environmental impacts of sulfate-based stratospheric aerosol injection. The sulfate emissions at the quantities necessary for climate response field tests or for full implementation of stratospheric aerosol injection, if conducted within the territory of a Party, would exceed the limits under these Protocols.

CLRTAP has a noncompliance procedure. Cases of possible noncompliance are first reviewed by the Implementation Committee, and decisions regarding how to respond are taken by the Executive Body. These bodies would be able to consider three mitigating factors when considering noncompliance with a CLRTAP Protocol due to stratospheric sulfate aerosol injection. First, these activities might reduce global warming and the harm therefrom. Second, the goal of CLRTAP and its Protocols is to reduce adverse effects on humans and ecosystems from air pollution, whose definition includes GHGs and perhaps global warming.[78] Although it would be in Parties' general interests to consider both the beneficial and adverse effects of atmospheric climate engineering activities, they are not obligated to consider the former under CLRTAP and its Protocols. Third, the sulfate particles injected into the stratosphere would be deposited across the globe, with a very small impact on the precipitation within Parties' territories. Therefore, although the sulfate emissions from SRM research or implementation might exceed a Party's limit, their effect on acid rain would be minimal.

3.3.2. *Marine Agreements*

Climate engineering and the world's oceans are deeply interrelated. Elevated atmospheric GHG concentrations will affect the oceans by warming and acidifying their waters and by raising the sea level. In turn, the oceans will moderate terrestrial climatic effects by serving as sinks for both GHGs and heat. Thus, regardless of their location, all climate engineering methods undertaken at sufficient scale would affect the oceans, at least indirectly, by reducing atmospheric carbon dioxide or incoming solar radiation and the resulting heat. Moreover, some climate engineering activities may actually take place in, on, or over the seas, either inherently – such as ocean upwelling or marine cloud brightening – or potentially – such as stratospheric aerosol injection performed from maritime vessels or platforms.

In some ways, the oceans resemble the atmosphere: physically in that they consist of a large body of a fluid that mixes through currents, and legally in that some portions of this body are demarcated as being within the sovereign territory of (some) states. The most important legal difference for present purposes is that there is a central comprehensive multilateral agreement that regulates most maritime activities, the UN Convention of the Law of the Sea. Most of this subsection consequently focuses on its lengthy text, but then looks at a pair of related agreements that govern dumping in the oceans. Notably, in the cases described here, either the multilateral agreement systems contain specific provisions for research, or their Parties have chosen to make such a distinction in their implementation. Consequently, they place climate engineering research and implementation in distinct legal lights.

3.3.2.1. United Nations Convention of the Law of the Sea

The world's oceans are historically the most important area beyond national jurisdiction, and have been the object of much international law.[79] The 1982 United Nations Convention on the Law of the Sea (UNCLOS) is a comprehensive multilateral agreement that established a legal and institutional setting for international cooperation to govern the activities of states and – indirectly – private actors in, on, and above the oceans. UNCLOS describes Parties' rights, duties, and other commitments in their maritime activities, including their obligations to protect the marine environment and their rights and duties in conducting marine scientific research. As such, it governs climate engineering activities that would take place in or be likely to impact the marine environment, including the atmosphere above the oceans. The agreement counts most countries – but not the USA – as Parties, and much of its content is considered to reflect customary international law, which applies to non-Party states as well.[80] UNCLOS is supported by regular meetings of its Parties; by dedicated bodies created by UNCLOS, including an International Tribunal of the Law of the Sea to resolve disputes; and by the International Maritime Organization (IMO), a specialized UN agency that predates UNCLOS.

Among its purposes, UNCLOS is an environmental agreement that provides that "States have the obligation to protect and preserve the marine environment" with neither qualification nor exception.[81] UNCLOS does not define the "marine environment," but the term is generally understood to include the entire space above (i.e., the atmosphere and the sea surface), within, and below (i.e., the seabed and subsoil) the oceans.[82] Parties' sovereign right to exploit their natural resources is explicitly subject to their duty to protect and preserve the marine environment.[83] In this context, climate engineering could be considered a means of exploiting the ocean's natural resources. For CDR, the natural resource would be the water's ability to absorb carbon. Applying this category to SRM is difficult but not impossible by, for example, considering the ocean's capacity to produce reflective clouds as a natural resource. Parties are also to cooperate in developing regulations for environmental protection.[84] Somewhat more specifically, the agreement addresses "pollution of the marine environment," defined in a manner very similar to that of CLRTAP as:

> the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities.[85]

Pollution can come from elsewhere, such as the land or the terrestrial atmosphere, provided that it impacts the marine environment. Therefore, for example, terrestrial CDR methods such as enhanced weathering (in which the captured carbon dioxide and dissolved minerals enter surface waters and subsequently the oceans) or land-based stratospheric aerosol injection could cause pollution of the marine environment. Furthermore, GHGs and probably global warming qualify under UNCLOS as pollution of the marine environment.[86] Unlike CLRTAP, the UNCLOS definition includes substances or energy that are merely likely to cause deleterious effects, not only those that have already done so. Parties' commitments concerning pollution of the marine environment include the following:

- "to take … all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source";

- to "ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment, and that pollution arising from incidents or activities under their jurisdiction or control does not spread beyond the areas where they exercise sovereign rights";
- to notify potentially affected Parties and competent international organizations when they become aware of actual or imminent pollution damage;
- to cooperate in eliminating the effects of pollution and in preventing or minimizing the resulting damage;
- to "take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control";
- to monitor the risks or effects of pollution and to publish the results therefrom;
- to assess and to communicate the expected effects of potential "substantial pollution of or significant and harmful changes to the marine environment"; and
- to adopt and enforce laws and regulations to reduce pollution, including from their own vessels, those that enter their territorial waters or their quasi-territorial exclusive economic zones (see below), land-based sources, and the atmosphere.[87]

Additionally, Parties are obligated to undertake their own measures, and to cooperate with others, to conserve living resources and mammals and "to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life."[88]

What these and other provisions mean with respect to climate engineering activities is uncertain. Their application would depend in part upon the extent to which the activity in question would reduce or would be likely to reduce the "pollution" of atmospheric GHG concentrations or global warming, as well as the extent to which the activity itself would result in or would be likely to result in deleterious effects. This dynamic is another example of the tension between climate change and climate engineering. At one extreme, if it were certain or likely that the activity would lessen the negative impacts from climate change on the marine environment and maritime activities, while posing little risk of its own, Parties with the capacity to do so might be obligated – at least theoretically – to undertake the climate engineering activity. The state would need to do so in a manner consistent with UNCLOS, including exercising due diligence by taking all measures necessary to minimize the deleterious effects of the climate engineering activity itself.[89]

At the other extreme, if the activity were unlikely to directly or indirectly reduce atmospheric GHG concentrations or global warming yet would cause or would be likely to cause large deleterious effects, then Parties would be committed to take all measures necessary to prevent, reduce, and control the climate engineering activity within their jurisdiction or under their control.[90] If substantial negative impacts were expected, the Party carrying out or overseeing the activity would need to assess and communicate these expected effects prior to undertaking it.[91] Because some of the greatest threats to the marine environment from elevated carbon dioxide concentrations come from the acidification of ocean waters, these considerations generally tilt in favor of CDR climate engineering methods, which could prevent, reduce, and/or control this effect, compared with SRM proposals, which would not directly reduce ocean acidification. Likewise, those climate engineering methods that would intervene more directly in the marine environment, such as ocean fertilization and microbubble injection, appear more likely to have deleterious effects on the marine environment than those that would do so less directly or only indirectly, such as stratospheric aerosol injection or terrestrial enhanced weathering. Here, UNCLOS would appear less favorable to the former (direct) than the latter (indirect) methods.

The tension and balance among the deleterious impacts of climate change, the potential for climate engineering to reduce these impacts, and climate engineering's own environmental risks are further complicated by a provision in UNCLOS: "In taking measures to prevent, reduce and control pollution of the marine environment, States shall act so as not to transfer, directly or indirectly, damage or hazards from one area to another or transform one type of pollution into another."[92] Climate engineering could transfer hazards from one area to another, such as from the atmosphere to the ocean, and might transform one type of pollution, such as global warming, into another, such as stratospheric sulfates that destroy ozone. (Notably, other responses to climate change, including emissions abatement and adaptation, as well as actions to reduce pollution in general done at sufficient scale, also sometimes transfer the location of damage or hazards and transform the type of pollution.) Notably, this article uses the strong verb "shall," and makes no explicit provision for the possibly lower relative magnitude and/or probability of the new damage, hazard, or pollution. Legal scholars have reached divergent conclusions regarding this article's implication for climate engineering. For example, James Edward Peterson concludes that "only if the process left harmful residues or byproducts would it appropriately be considered polluting."[93] Yet Philomene Verlaan calls it "a particularly difficult hurdle for geo-engineering projects," and asserts that "[p]roponents of geo-engineering projects must show, inter alia, why such projects do not violate Article 195."[94] However, note that the oceans presently absorb approximately one-third of anthropogenic carbon dioxide emissions.[95] Once emissions reduce and cease, this process will continue, eventually removing most of the remaining anthropogenic carbon dioxide until the atmosphere and ocean reach a new equilibrium. In this regard, some CDR methods would arguably not be a transfer and transformation, but instead merely the acceleration of a process that is already occurring in response to anthropogenic disturbance to the atmosphere.

Because UNCLOS contains numerous provisions regarding marine scientific research, climate engineering research would face different legal circumstances than would implementation. Although UNCLOS generally supports and encourages "marine scientific research," the term remains undefined. Most definitions considered during the drafting of UNCLOS and in legal scholarship emphasize the importance of the marine environment as the object of study, but diverge on whether the research must occur in the marine environment.[96] Climate engineering research is discussed in detail in Chapter 6 of this volume, but it is noted here that the situation is complicated by the fact that there is often no clear distinction between outdoor research and implementation for many climate engineering methods. Regardless, Parties and competent international organizations have a right to conduct marine scientific research, and are obliged, among other things, to

> "promote and facilitate the development and conduct of marine scientific research"; to "promote international cooperation in marine scientific research"; "to create favourable conditions for the conduct of marine scientific research in the marine environment"; and "to make available … information on proposed major programmes and their objectives as well as knowledge resulting from marine scientific research."[97]

In fact, Parties are committed "to observe, measure, evaluate and analyse, by recognized scientific methods, the risks or effects of pollution of the marine environment."[98] This obligatory category could include both climate change and climate engineering, as they each pose risks of pollution of the marine environment. However, Parties' right to conduct research is subject to some limitations, most generally "to the rights and duties of other States."[99] More specifically, marine scientific research shall

> "be conducted exclusively for peaceful purposes"; "be conducted with appropriate scientific methods and means"; "not unjustifiably interfere with other legitimate uses of the sea"; and "be conducted in compliance with all relevant regulations … including those for the protection and preservation of the marine environment."[100]

As discussed in more detail below, Parties and sponsoring international organizations are responsible for and might be held liable for damage resulting from scientific research undertaken.[101]

Parties' rights, obligations, and other commitments with respect to climate engineering will vary based upon the location of the activity. This factor is somewhat complicated in that the jurisdiction over ships and their activities is partially shared among states. Across the seas, ships must fly the flag of a particular state that has given them permission to do so and to which the ship has a genuine link.[102] The flag state is supposed to exercise its jurisdiction over its flagged ships, including by ensuring that its crew is familiar with regulations concerning marine pollution and by adopting laws and regulations to minimize pollution from its flagged ships.[103] Furthermore, UNCLOS divides the water, water surface, and atmosphere horizontally into three primary zones of jurisdiction of coastal states. The first 12 nautical miles from shore is the territorial sea of the coastal state, and is part of its sovereign territory.[104] Activities other than innocent passage are subject to the approval of the coastal state.[105] Climate engineering activities would not be innocent, at the very least because the foreign ship would be engaged in an "activity not having a direct bearing on passage."[106] Coastal states' jurisdiction in their territorial waters also includes "the exclusive right to regulate, authorize and conduct marine scientific research," and research there by foreign ships requires their express consent.[107] Coastal states have a right to enforce their laws and regulations in territorial waters, including through detention and physical inspection of ships and through punishment by expulsion from their territorial seas, monetary penalties, arrests (in some circumstances), and – in the case of willful and serious pollution – unstated nonmonetary penalties.[108] Coastal states arguably have an obligation to take such enforcement action.[109]

The second primary jurisdictional zone defined by UNCLOS is the coastal state's exclusive economic zone (EEZ), which is the first 200 nautical miles from the coast.[110] There, the coastal state has sovereign rights over "exploring and exploiting, conserving and managing the natural resources, whether living or non-living … and with regard to other activities for the economic exploitation and exploration of the zone," as well as jurisdiction over installations and structures, marine scientific research, and protection of the marine environment.[111] In exercising its limited jurisdiction in the EEZ, the coastal state and other states must have due regard for each other's rights and duties.[112] States and, consequently, their flagged ships in an EEZ must comply with the laws and regulations of the coastal state.[113] The enforcement rights of a coastal state and its jurisdiction over marine scientific research, such as climate engineering research, in its EEZ (which hereinafter refers to the EEZ beyond the coastal state's territorial waters) are somewhat similar to those in its territorial waters.[114] However, the coastal state should also grant its consent for marine scientific research "in normal circumstances."[115] In turn, the researching state must provide certain information to the coastal state, both before and during the research project. This obligation includes ensuring that the coastal state may participate in or be represented in the research project if it so wishes.[116] As noted above, climate engineering implementation might qualify as a means of exploiting or managing the ocean's nonliving natural resources. Under such an interpretation, coastal states would have sovereign rights over the climate engineering activities in question within their EEZs. Regardless, any dispute concerning activities in the EEZ between the flag state and the coastal state "should be resolved on the basis of equity and in the light of all the relevant circumstances, taking into account the respective importance of the interests involved to the parties as well as to the international community as a whole."[117] This proviso implies that the severity of climate risks that the states face and the potential for the climate engineering activity to reduce (or exacerbate) the risks are relevant factors in resolving the conflict.

The third and final marine zone is the high seas, which lie beyond the EEZs and are open to all states for peaceful purposes, including marine scientific research, provided that the states exercise their freedoms there "with due regard for the interests of other States."[118] Thus, climate engineering and other activities on the high seas should not inappropriately interfere with, inter alia, the navigation, overflight, fishing, and scientific research of other states.[119] In the event of an incident on the high seas that results in serious damage to the marine environment or other vessels, the flag state is to hold an inquiry.[120] As an aside, states' rights in the high seas and in the EEZs of other states include the right to overflight, and thus their various rights and duties in these zones described above would extend to atmospheric-based climate engineering activities undertaken there.[121]

One particular challenge on the high seas is the regulation of ships that bear the flag of a non-ratifying state or no flag at all. For example, a ship that was reportedly flying the flag of a Canadian indigenous people's village conducted rogue ocean fertilization in the high seas in 2012.[122] It is reasonable to conclude that Parties might be responsible for the activities of their nationals in such circumstances. However, UNCLOS is not entirely clear to what extent its provisions regarding the marine environment and marine scientific research extend to Parties' nationals. On one hand, several of the key articles regarding preventing, reducing, and controlling pollution commit Parties to take measures regarding "activities under their jurisdiction or control," whereas others refer to "their natural or juridical persons," suggesting that the former duties do not extend to the activities of the latter group.[123] On the other hand, Parties can exercise some control over their nationals, and their obligations to protect and preserve the marine environment in general and to take all measures to minimize pollution from any source are without any qualification regarding their jurisdiction or control.[124]

In four articles, UNCLOS establishes, or at least reaffirms, liability for damage from Parties' activities at sea, for the most part limited to damage from acts that are contrary to UNCLOS or to international law generally. Some of these provisions could apply to climate engineering activities that cause harm, depending on the circumstances at hand and on the interpretation of the articles. The first and most generally relevant article addresses liability for harm from pollution to the marine environment, which, as discussed above, could include climate engineering activities and/or the results of such activities if certain conditions were satisfied.[125] This article states that "concerning the protection and preservation of the marine environment [Parties] shall be liable in accordance with international law." This language implies the application of the existing customary international law of state responsibility, in which states are responsible – including but not limited to providing "reparation –" for harm to other states from their acts that are contrary to international law. More specifically, it only requires Parties to "ensure that recourse is available in accordance with their legal systems for prompt and adequate compensation or other relief in respect of damage caused by pollution of the marine environment by natural or juridical persons under their jurisdiction."[126] This provision establishes only a procedural standard for compensation – not a substantive one for state liability – for harm from pollution arising from acts that are not necessarily contrary to international law. Furthermore, under this article UNCLOS Parties are also to cooperate in implementing and further developing international law relating to liability for pollution damage. A second article in UNCLOS establishes similar standards for liability for pollution damage arising from marine scientific research.[127] Unlike the more general article regarding pollution described above, which merely refers to existing international law, this one explicitly states that Parties and international organizations will be liable for such damage due to research that they or their citizens undertake and that is somehow contrary to UNCLOS. In the third relevant UNCLOS article, Parties are liable for damages and loss from their enforcement of laws and regulations with respect to pollution of the marine environment when the enforcement measures are "unlawful or exceed those reasonably required in the light of available information."[128] This provision could apply, for example, either to Parties' efforts to prevent, reduce, or control the pollution arising from climate engineering, or more speculatively, to their own climate engineering activities if these were undertaken with the intent for the activities to function as an enforcement mechanism against the pollution by GHGs or global warming.[129] The fourth article establishes state liability for harm to the seabed, ocean floor, and subsoil thereunder, again only for harm arising from noncompliance with UNCLOS.[130]

A few additional notes regarding liability for marine activities are necessary. The four provisions in UNCLOS described above imply the existence of a harmed victim who can pursue compensation, yet marine life – which is among the possible victims in the definition of pollution of the marine environment – that is not a living resource and that is located in the high seas, cannot be represented by a state or private person in order to claim compensation.[131] Additionally, UNCLOS leaves the scope of "damage" and "loss" undefined. Finally, the International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea would create a two-tier civil liability system paid for through mandatory insurance and an industry-wide fund.[132] Shipowners would be held strictly liable for damage, including environmental damage, from specific substances that are shipped by sea. The most widely considered material for stratospheric aerosol injection – sulfur in various forms – is on the list of substances, and future climate engineering techniques could utilize other hazardous and noxious substances. However, this agreement is not in force due to the absence of ratifying states, and this appears unlikely to change soon.

In one part of UNCLOS, Parties make various commitments to develop and transfer marine technology, especially to developing states. This obligation could apply to climate engineering technologies, depending on how one interprets the undefined term "marine technology" and the particular climate engineering technology at hand. Most generally, Parties are "to promote actively the development and transfer of marine science and marine technology on fair and reasonable terms and conditions."[133] The commitment to the "development of the marine scientific and technological capacity of States which may need and request technical assistance in this field" is explicitly with regard to "the protection and preservation of the marine environment, marine scientific research and other activities in the marine environment," strengthening the case that some of these provisions could apply to climate engineering.[134] This is to be done with due regard for the rights and duties of the holders, suppliers, and recipients of marine technology.[135] Together, these provisions could reasonably be interpreted as committing industrialized UNCLOS Parties to the development of climate engineering methods and the transfer of these technologies to developing countries on terms that do not unduly harm patent holders and others with interests in the production of these technologies.

Four particular categories of climate engineering methods are examined more closely here due to their possible locations or means of operation. First, direct air capture and BECCS technologies, which would qualify as climate engineering depending upon their scale, could store the captured carbon dioxide on or under the seabed.[136] There are provisions in UNCLOS regarding the seabed and the subsoil thereunder.[137] These were crafted to govern the exploration and exploitation of natural resources – especially fossil fuels – there. However, some articles could apply to the seabed surface or subsurface storage of carbon dioxide. The zones, rights, and obligations at these deep locations differ somewhat from those of the superjacent water, water surface, and atmosphere described above, although most of the provisions in UNCLOS regarding the protection of the marine environment and the minimization of pollution apply to all locations. Coastal states have certain sovereign rights to the seabed and subsoil of their continental shelves, a zone that includes at least the seabed surface and subsurface under states' EEZs, but that can extend further into the area under the high seas depending on the topology of the seabed.[138] Among coastal states' rights there is the exclusive right "to authorize and regulate drilling on the continental shelf for all purposes," which would presumably include sub-seabed carbon dioxide storage.[139] Beyond the continental shelf lies "the Area," which is governed in a manner that is novel in international law.[140] It is designated in UNCLOS to be the common heritage of mankind, managed and regulated by the International Seabed Authority. Conduct there must be "in the interests of maintaining peace and security and promoting international cooperation and mutual understanding," and only for peaceful purposes.[141] The International Seabed Authority has the authority to develop regulations to protect the marine environment of the Area.[142] As stated above, Parties are explicitly liable for damage caused by their conduct in the Area that fails to comply with the UNCLOS.[143] Both Parties and the International Seabed Authority may carry out marine scientific research there, provided that the researching states promote cooperation.[144]

Numerous regional multilateral agreements supplement UNCLOS regarding maritime activities and protection of the marine environment. Although this chapter does not examine these in detail, it should be noted that the Convention for the Protection of the Marine Environment of the North-East Atlantic, which is in effect and has been ratified by 16 Parties, has been amended to permit and regulate the storage of captured carbon dioxide below the seabed of the northeastern Atlantic Ocean.[145]

The second category of climate engineering methods operate through the placement of diffuse substances into the marine environment. This group includes CDR proposals such as ocean fertilization, ocean alkalization, and direct air capture followed by injection of carbon dioxide into the water column. It could also include maritime SRM by injection of microbubbles, stratospheric aerosol injection, or marine cloud brightening as well as cirrus cloud thinning. Both sets of methods might (or might not) be considered dumping, which the UNCLOS defines as "any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea," but excludes "placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention."[146] Based on an ordinary interpretation of these words, the purpose of placing fertilizing or alkalinizing matter in the ocean, or the injection of aerosols or fine ocean mist, would not be *mere* disposal of those substances, but instead would be to indirectly remove carbon dioxide from the atmosphere or to reduce climate change risks in some other manner. This logical exclusion from dumping would require that the practice not be contrary to UNCLOS's unstated aims. Based upon its Preamble and its numerous commitments, these implicitly include protection of the marine environment, raising the tension between and consequently the balance of climate change and climate engineering.[147] For example, if ocean fertilization were likely to have or actually had deleterious effects, it would qualify as pollution of the marine environment, especially if it sequestered little carbon dioxide relative to its own deleterious effects. If this impact were known or expected in advance, the activity appears to be contrary to the aims of UNCLOS, and would therefore be dumping.[148] There would be some question whether marine cloud brightening, microbubble injection, and ocean upwelling would also be considered dumping, because these practices would merely involve the movement of natural material from one location to another within the marine environment. In contrast, the injection of captured carbon dioxide into the water column *does* appear to be the mere disposal thereof. Note that the definition of dumping does not include matter such as carbon dioxide from land-based sources that is transported to the marine environment via pipelines or outfall structures; that would potentially be pollution from land-based sources.[149]

Regardless, Parties are to prevent, reduce, and control pollution of the sea by dumping.[150] This requires that the dumping be likely to cause deleterious effects, which may or may not be the case with these marine climate engineering methods, depending upon their modality, quantity or magnitude, and location. Coastal states have the right to regulate dumping in their EEZs, where the practice requires their prior consent.[151] The Parties to UNCLOS are to establish global and regional regulation regarding dumping in order to reduce the pollution that arises from it.[152] Moreover, Parties' national laws "shall be no less effective … than the global rules and standards."[153] International regulation has been developed and implemented largely through the London Convention and London Protocol, considered below, although participation in these agreements is not as broad as that of UNCLOS. A possible interpretation, albeit an unsettled and controversial one, is that UNCLOS Parties that are not parties to the London Convention and/or the London Protocol are nevertheless committed to some or all aspects of those dumping-specific agreements.[154]

With regard to the third category of climate engineering methods, some researchers believe that marine cloud brightening SRM could be carried out by numerous unmanned boats. Although the interchangeable words "ship" and "vessel" remain undefined in UNCLOS, they are widely understood to include unmanned ships. They would therefore be required to bear the flag of a state to which they have a genuine link. That flag state would need to issue laws and regulations to prevent, reduce, and control the ships' potential pollution of the marine environment, and to conduct an inquiry in the event that the ship causes serious damage to the marine environment.[155] Nevertheless, some legal uncertainties arise with the deployment of unmanned ships, whether for climate engineering or for other purposes.[156] Specifically, UNCLOS gives certain responsibilities to the ship's master, officers, and crew, none of whom would be present on unmanned ships. For example, the flag state of a ship must take measures

> "to ensure … that each ship is in the charge of a master and officers who … are fully conversant with and required to observe the applicable international regulations concerning the safety of life at sea, the prevention of collisions, the prevention, reduction and control of marine pollution, and the maintenance of communications by radio."[157]

To some extent, the shore-based vessel operator(s) could be considered as fulfilling these roles. Other questions surround who would be liable for accidents or violations of international or coastal state laws and regulations. Another set of concerns regards how to ensure that unmanned ships would navigate the seas in such a manner that they would have due regard for the rights and interests of other states. This includes not hindering other ships' navigation and not entering other states' territorial water or – in some circumstances such as unauthorized marine scientific research – their EEZs.

In the fourth category, some marine climate engineering methods, particularly ocean upwelling, could function through objects that are placed and left in the ocean.[158] Parties' rights and obligations under UNCLOS regarding this are somewhat confusing in that the agreement usually – but not always – uses the undefined terms "artificial islands, installations and structures" in the general context and "installations and equipment" in the context of marine scientific research, yet in some passages omits one or either of these terms.[159] Regardless, throughout the ocean, Parties' obligation to take measures to minimize pollution of the marine environment explicitly extends to "pollution from other installations and devices operating in the marine environment."[160] Installations or equipment for research must bear the identifying markings of the state of registry or the international organization to which they belong.[161] In the EEZs or on the continental shelves, coastal states have jurisdiction over these placed objects, including the exclusive right to construct, authorize, and regulate artificial islands, installations, and structures.[162] Further, due notice must be given of their construction.[163] Although coastal states are to grant permission under normal circumstances for other states to conduct marine scientific research in their EEZs and on their continental shelves outside their territorial waters, "the construction, operation or use of artificial islands, installations and structures" is one of four justifications for them to deny such permission.[164] For marine scientific research in all locations, unused installations, structures, and equipment must be removed; artificial islands, installations, and structures may have a designated zone of safety; and all categories of placed objects may not interfere with existing sea lanes.[165] On the high seas, all Parties have the "freedom to construct artificial islands and other installations permitted under international law," provided that they exercise due regard for the exercise of high seas freedoms by other states.[166] Moreover, because objects placed in the water for climate engineering might be (and are presently imagined mostly to be) free floating, the Party that oversees their placement would need to ensure that they do not migrate into the EEZ of another state.

Although the possible application of UNCLOS to particular scenarios of climate engineering remains uncertain in many ways, the agreement might be able to provide a legal and institutional home for future governance of a wide array of climate engineering activities due to a handful of remarkable characteristics. UNCLOS contains numerous commitments that use legally binding language for the prevention, reduction, and control of pollution. This pollution can include GHGs, global warming, and potentially harmful climate engineering activities if their actual or expected negative effects occur in the marine environment. This encompasses the ocean's water and atmosphere, and cases in which the pollution originates from the atmosphere or land. The threshold of "likely to result in such deleterious effects" extends potential governance of climate engineering to an anticipatory stage. Furthermore, most countries are Parties to UNCLOS, and the major one that is not – the USA – explicitly considers most of it to reflect customary international law, including the parts regarding protection of the marine environment and marine scientific research.[167] UNCLOS Parties generally meet annually and can adopt amendments to the Convention. There is a standing International Tribunal for the Law of the Sea to resolve disputes, and the IMO offers an institutional home.[168] Of course, UNCLOS is not perfect for regulating climate engineering: Many of its commitments are vague, and its institutions' exercise of authority over climate engineering activities could lead to conflicts with the provisions of the UNFCCC.

3.3.2.2. London Convention and London Protocol

The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and the London Protocol thereto are a pair of multilateral treaties that focus upon reducing marine pollution from dumping. They are both in effect and institutionally supported by the IMO. As noted above, they might represent the global rules and standards to which UNCLOS refers, and could therefore be legally binding to some extent on those Parties to UNCLOS that are not Parties to the London Convention and London Protocol.[169] The 1972 London Convention has 87 Parties, including all major industrialized maritime countries, as well as a handful of countries – including the USA – that are not Parties to UNCLOS. In contrast, the 1996 London Protocol – which is intended to replace the London Convention and supersedes the conventions for those states that are Parties to both – presently has 45 Parties, a cohort that lacks major states such as the USA and Russia.[170] Their specific objectives, stated in the obligatory language of "shall," refer to the control of *all* sources of pollution of the marine environment, especially that from dumping.[171] The two agreements apply to all maritime waters, including the high seas, EEZs, and non-inland territorial waters, as well as to the Parties' flagged ships and loading that occurs in their ports. The Protocol uses somewhat stronger language than the Convention and, unlike the Convention, actually defines pollution.[172] Although that definition is mostly similar to that of UNCLOS, it is limited to matter – not including energy – and thus could encompass elevated atmospheric and dissolved greenhouse gases and possibly some climate engineering methods, but not global warming. Among other things, Parties to the London Protocol are committed to promote scientific research on pollution from dumping and from "other sources of marine pollution relevant to this Protocol." The latter presumably includes research into marine CDR, especially those forms that may constitute dumping.[173] Furthermore, Parties may not "transfer, directly or indirectly, damage or likelihood of damage from one part of the environment to another or transform one type of pollution into another."[174] Although this clause resembles that in UNCLOS, its application is limited to Parties' actions in implementing the Protocol.

Most commitments in these two agreements are specific to pollution from dumping, despite their broader objectives. The definitions of dumping in the agreements are very similar to those in UNCLOS, in particular retaining the exception for purposes "other than the mere disposal thereof, provided that such placement is not contrary to the aims of" the agreement.[175] The older Convention uses a "black list" of prohibited substances that may not be dumped (with the dumping of non-prohibited substances subject to impact assessment) and a "gray list" of substances that require a special permit, while all other substances to be dumped require a general permit.[176] Most substances that are presently considered for placement into the water for climate engineering purposes, such as iron and carbon dioxide, are found on neither the "black list" nor the "gray list." However, the latter does categorically include those substances "which, though of a non-toxic nature, may become harmful due to the quantities in which they are dumped, or which are liable to seriously reduce amenities."[177] Consequently, climate engineering activities that were considered to be dumping and were of a sufficient scale would require a special permit under the terms of the London Convention. In contrast, the newer London Protocol generally prohibits dumping except for a "gray list" of substances that require a permit, while "being mindful of the Objectives and General Obligations of this Protocol."[178] That "gray list" includes "inert, inorganic, geological material" and "organic material of natural origin," terms that are not defined and whose applicability to substances used in climate engineering could be clarified in a permitting process. Furthermore, Parties to the London Protocol commit to applying "a precautionary approach to environmental protection from dumping of wastes or other matter whereby appropriate preventative measures" are taken, even in the absence of "conclusive evidence to prove a causal relation between inputs and their effects."[179]

The Parties to the two agreements, which meet jointly, have taken several actions regarding ocean fertilization.[180] In response to the stated intentions of for-profit enterprises to fertilize the oceans and subsequently market carbon credits, the Parties approved a resolution in 2008 stating that ocean fertilization ("any activity … with the principle [*sic*] intention of stimulating primary productivity in the oceans [excluding] conventional aquaculture, or mariculture, or the creation of artificial reefs") falls within the scope of the two agreements.[181] The nonbinding resolution also concluded that ocean fertilization should generally not be allowed with the exception of legitimate scientific research, which should not be considered to be dumping and should be assessed on a case-by-case basis.[182] The Parties to the two agreements later developed a framework – also nonbinding – for such assessment for scientific research involving ocean fertilization.[183] Under this, Parties are to first determine whether the planned activity would indeed be ocean fertilization and have the attributes of legitimate scientific research: adding to scientific knowledge, not having direct financial gain and the influence therefrom, being subject to peer review, and committing to publish in a peer-reviewed outlet and to make data publicly available.[184] If this is the case, the agency would subsequently conduct an environmental impact assessment that should include, inter alia, site selection and description, exposure assessment, risk characterization, and risk management.[185] The latter process, as well as the ultimate approval decision, should follow a "precautionary approach," which is not elaborated but can be interpreted as being consistent with that of the London Protocol.[186] Prior to any approval, the researching Party should consult with all stakeholders and notify potentially affected countries. Notably, the assessment framework is adaptive, in that the approval can be modified or revoked based upon the content of the required reporting.

In 2013 the Parties to the London Protocol approved a broader amendment to that agreement, which would regulate "marine geoengineering" in general. The amendment – not yet in force – defines this as:

> a deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, long lasting or severe.[187]

When and if this amendment comes into effect, the Parties would collectively maintain a new Annex 4 to the Protocol, listing specific marine geoengineering activities.[188] Notably, a two-thirds majority of its Parties that are present and voting can modify the Protocol's Annexes.[189] The Parties would then be committed to not allowing the placement of matter into the sea for these activities, unless the Annex's particular listing allows for case-by-case authorization by the Party.[190] Placement of matter for marine geoengineering activities that are not listed in the Annex is implicitly permitted, provided that this placement is neither dumping nor contrary to the Protocol's aims. Presently, the list in the Annex includes only ocean fertilization, which Parties should permit only if the activity is legitimate scientific research.[191] Parties would need to adopt administrative or legislative measures to ensure that pollution to the marine environment from these listed activities is, as far as practicable, prevented or minimized and that the activities are not contrary to the Protocol's aims.[192]

The case-by-case authorizations should follow both a general assessment framework as well as any specific assessment framework for that particular activity. The former is intended to be legally binding upon the Parties that ratify the amendment and is detailed in another new Annex, whereas the latter will be nonbinding and approved by the meetings of Parties.[193] Under the general, legally binding assessment framework, the Party in whose jurisdiction or under whose control the proposed activity would occur is to require a detailed description of the activity, to notify potentially affected countries, and to develop a consultation plan.[194] The activity's proponents must demonstrate that the activity is not mere disposal, that it would fulfill its purpose, that its "rationale, goals, methods, scale, timings and locations as well as predicted benefits and risks" are justified, and that they have the financial resources to carry out the proposed activity adequately.[195] The responsible Party is also to encourage consultation with all stakeholders, and consent – while not required – "should be sought from all countries with jurisdiction or interests in the region of potential impact."[196] Furthermore, the Party and any potentially affected countries should seek expert advice, including peer review of proposals.[197] Ultimately, a permit requires that the proposal has satisfactorily completed all assessments, impact evaluations, and consultation requirements; that it would fulfill its purpose; that the risk management and monitoring requirements have been determined; that the proposal's environmental harm would be minimized while benefits would be maximized; and that pollution would be minimized as far as practicable.[198]

The approved Annex also offers a non-exhaustive list of reasons that some potential marine geoengineering techniques may require specific marine scientific research, and describes the characteristics that constitute such research as well as the conditions that should be imposed upon it.[199] These required conditions are similar to those found in the nonbinding assessment framework for ocean fertilization – i.e., adding to scientific knowledge, having no direct financial gain and the influence therefrom, being subject to peer review, and committing to publish in a peer-reviewed outlet and to make data publicly available. The Annex adds to these the requirement of an appropriate research methodology and sufficient financial resources to carry out the proposed research activity. The two paragraphs concerning marine scientific research are not related explicitly to any particular obligation, but instead appear to be intended to guide the assessment of listed marine geoengineering activities that are limited to or might have alternative assessment criteria for legitimate scientific research.

This amendment to the London Protocol, although not yet in force, is notable in several regards. First, it is the only instrument of international law that is intended to be legally binding upon states and is specifically concerned with climate engineering, although the definition of marine geoengineering is not limited to climatic purposes. In fact, this definition – likewise the first of its type in a binding legal instrument – includes SRM and cirrus cloud-thinning activities, at least those that take place at sea.[200] Second, the amendment relies upon an expansive interpretation of the Protocol's scope, which is not limited to dumping. Instead, as noted, it also includes a commitment to "protect and preserve the marine environment from all sources of pollution," which is recalled in the recitals found in the resolution's Preamble.[201] Furthermore, the amendment's regulatory scope concerns all placement of matter for marine geoengineering, not only dumping. Indeed, the listed marine geoengineering activities will be exempt from the Protocol's central article that prohibits dumping.[202] Third, as with marine geoengineering, criteria for marine scientific research are laid out in a legally binding international legal instrument for the first time.[203] These characteristics of and conditions for marine scientific research, which are also found in similar form in the earlier nonbinding assessment framework, could help clarify that concept in the context of UNCLOS, where the phrase is oft-repeated – including in a freedom to conduct it on the high seas – yet is undefined. Although the Parties to the London Protocol lack the authority to modify UNCLOS, these characteristics and conditions are consistent with UNCLOS's rights and obligations regarding marine scientific and could provide rough contours as to how some members of the international community delineate marine scientific research. Finally, the amendment explicitly adopts a balancing approach to the tension between climate change and climate engineering, calling for "conditions [to be] in place to ensure that, as far as practicable, environmental disturbance and detriment would be minimized and the benefits maximized."[204]

As a final additional note, direct sequestration in the water column, or on or under the seabed, of carbon dioxide that has been captured at sea would qualify as dumping under the London Convention and the London Protocol. In 1999 the Parties to the former received a report from its Scientific Group, which concluded that "fossil fuel derived CO_2 was considered an industrial waste" – a prohibited category. However, they did not reach consensus on this issue, and the legal status of the placement of captured carbon dioxide into the water column consequently remains unclear under the London Convention.[205] The Parties to that agreement did, however, later adopt and subsequently revise guidelines on the storage of carbon dioxide in sub-seabed geological formations.[206] Parties amended the newer London Protocol – whose definition of dumping explicitly includes matter placed in the seabed and the subsoil thereof – almost immediately after it entered into force, in order to allow marine sequestration of carbon dioxide streams only below the surface of the seabed, prohibiting them in the water column or on the seabed surface.[207] A further amendment to the Protocol was approved in 2009, but is not yet in force, that would allow for the international export of captured carbon dioxide for sub-seabed storage.[208]

3.3.3. *Procedural Agreements*

States' obligations under international environmental law are often procedural in nature. Indeed, most multilateral agreements reviewed in this section rely heavily on procedural duties, as does the customary international law discussed below.[209] Two agreements developed under the UNECE solely rely upon procedural duties, and could apply to climate engineering activities.

3.3.3.1. Convention on Environmental Impact Assessment in a Transboundary Context

The Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention) is the first of two procedure-based multilateral environmental agreements developed through UNECE. Finalized in 1991, its current 45 Parties include the European Union, several former Soviet countries, and Canada. If a proposal, such as one for climate engineering activity, is subject to a decision of a national competent authority, then it is a "proposed activity" per the Convention.[210] Although the Espoo Convention's definition of "impact" has a very low threshold ("any effect caused by a proposed activity on the environment … includ[ing] effects on cultural heritage or socio-economic conditions resulting from alterations to" the environment), the obligations in the Convention are limited to cases of actual or likely significant adverse transboundary impacts.[211] The qualifier "transboundary" refers only to those impacts that are experienced in the jurisdiction of one Party and originate from that of another. Most outdoor climate engineering activities will have impacts; many will be subject to regulatory decisions by national authorities; and some of those activities of sufficient scale may cause significant adverse transboundary impacts on other Parties.

The only commitments that apply to all significant adverse transboundary impacts require Parties to "take all appropriate and effective measures to prevent, reduce and control significant adverse transboundary environmental impact from proposed activities."[212] The Parties of the Espoo Convention are also to "give special consideration to" establishing and expanding research programs for better understanding environmental impacts, a soft obligation that could encourage climate engineering research programs.[213] The other commitments mostly apply to only the specific proposed activities listed in an Appendix, none of which could be reasonably construed to include any of the climate engineering techniques that are currently suggested.

However, a proposed activity that is not listed but is deemed likely to have significant adverse transboundary impacts can still be subject to the obligations of the Espoo Convention. For this, a concerned Party (presumably the state of origin of the unlisted proposed activity) is obligated to enter into discussions with another Party (presumably a potentially affected state), and if they both so agree, they are to treat the proposed activity as if it were listed.[214] The Convention recommends some criteria of size, location, and effects that the Parties can use in this consideration.[215] Large-scale climate engineering research and certainly its deployment could satisfy these. When and if Parties agree to this, then the Party of origin is subject to a number of procedural obligations. These include, prior to a decision to authorize, conducting an environmental impact assessment that provides particular information, such as a description of the proposed activity, details of its likely impacts, possible steps to mitigate adverse impacts, potential alternative activities, and uncertainties.[216] The Party of origin is obligated to notify and consult with other affected Parties.[217] In particular, the publics in the likely affected areas are to have the opportunity to participate.[218] The Party of origin should take the outcome of the assessment, the public comments, and the international consultations into account in making the final decision regarding whether and how to proceed with the proposed activity.[219] The Espoo Convention also calls on its Parties, "to the extent possible," to conduct environmental assessments on their relevant policies, plans, and programs, implicitly only those that concern activities covered by the Convention.[220]

The Espoo Convention is supplemented by its Protocol on Strategic Environmental Assessment, which entered into force in 2010, and presently has 26 European Parties, including the European Union. They commit to undertake strategic environmental assessments of certain listed categories of official draft plans and programs that are likely to have significant environmental or health effects.[221] This obligation might extend to plans and programs for climate engineering, particularly for some CDR techniques.[222] Notably, the definitions of likely effects to be considered include, among other things, those on climate.[223] Parties to this Protocol also commit to ensuring the public availability of relevant information, and to providing opportunities for public participation and consultation.[224] If a plan or program would likely have significant transboundary environmental and/or health effects, the Party of origin is to notify and consult with the potentially affected Party, including providing an opportunity for public comment in the affected state.[225]

3.3.3.2. Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters

The 1998 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (the Aarhus Convention) is another UNECE multilateral environmental agreement that relies upon procedural obligations. In this case, its 47 Parties pursue the three objectives given in the Convention's title, which they generally guarantee as rights.[226] In this sense, the Aarhus Convention resembles a human rights agreement more than a traditional environmental one. In contrast to most multilateral environmental agreements, the effects of concern need not be transboundary. Thus, Parties are to offer these rights to the public of the state of origin of the environmental information or proposed activity, as well as to the publics of other Parties, in a nondiscriminatory manner.[227]

Concerning the first objective, "environmental information" is information that concerns the state of the environment and its elements as well as factors – including public policies, plans, and programs, and the analyses upon which they are based – that affect or are likely to affect the environment.[228] Climate engineering activities such as outdoor tests and implementation clearly fall within this definition. Parties' public authorities must make such relevant environmental information available to the public in accordance with requirements, such as timeliness, and with limitations, such as preventing adverse effects on intellectual property rights.[229] Requests for information do not need to demonstrate a particular interest, such as actual or potential harm. The public authorities are also to proactively establish and maintain systems for the collection and dissemination of environmental information.[230]

Regarding the second objective, the public that might be affected, as well as environmental nongovernmental organizations, have the right to participate in decision-making regarding whether to permit proposed activities that could affect the environment, which would include many climate engineering activities. This right could include any activities specifically listed in the Convention's Annex, any activity for which domestic impact assessment legislation provides public participation, or unlisted activities that might have a significant effect on the environment.[231] Once this obligation is triggered, Parties must ensure that the affected public and environmental groups are informed and given access to relevant information and the opportunity to participate, including by providing comments. This participation and comments are to be taken into account by public authorities in their decision-making. Some of these provisions extend, with qualifications, to plans, programs, and policies.[232]

The third objective of the Aarhus Convention, access to justice, is intended to address deficiencies in how Parties have carried out the first two objectives. It is achieved by setting minimum standards for redress for members of the public who have been denied environmental information or who wish to challenge a prior decision concerning environmental matters in which they have a sufficient interest.[233] In this, the Parties are to ensure that courts or other independent tribunals can enforce the rights granted in the Aarhus Convention. The Convention also has relatively strong, novel noncompliance procedures.[234]

The Aarhus Convention is furthered by its Kiev Protocol on Pollutant Release and Transfer Registers, which is in effect through the participation of 32 states as well as the European Union. Its Parties are to ensure the public availability of information regarding transfer and release of pollutants.[235] In this context, a pollutant is any substance that may be harmful to human health or the environment due to its introduction into the environment, and includes both accidental and deliberate release.[236] Thus, substances intended for use in climate engineering might qualify as pollutants. The Protocol's Parties are to establish and maintain a publicly accessible register of such information, which is to include information from private actors acquired via mandated reporting.[237] The Protocol's Parties are to be guided by the precautionary approach in their implementation of the Protocol.[238]

3.3.4. *Other Multilateral Environmental Agreements*

3.3.4.1. Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is one of the most important and far-reaching multilateral environmental agreements. Agreed at the 1992 UN Conference on Environment and Development in Rio de Janeiro, it now includes almost all of the world's countries – except the USA – among its Parties. The CBD can be described as a framework treaty whose commitments are broad, general, and often weakened through qualifying language. Its objective extends beyond the conservation of biological diversity to encompass the sustainable uses of biological resources and the equitable sharing of benefits from genetic resources.[239] With respect to its conservation objective, climate engineering as a response to the risks of climate change could have positive, negative, or mixed impacts on biological diversity.[240] Furthermore, because many human activities, such as climate engineering activities, undertaken at sufficient scale will affect biodiversity, the CBD's broad scope and robust institutional support have led it to function as a vehicle for environmental protection in general. Indeed, its implementation has touched upon issues as diverse as economic development, trade, agriculture, tourism, and climate change.

Two principles and two commitments of the CBD are, in general, relevant for climate engineering activities that might affect biodiversity. The Convention's singular explicit guiding principle is a restatement of states' sovereign right to exploit their own natural resources and their concomitant responsibility to prevent transboundary harm.[241] The CBD also invokes precaution, but only by "noting" it in the document's Preamble. In terms of commitments, the CBD Parties are, "as far as possible and as appropriate," to identify activities that have or are likely to have significant adverse impacts on biodiversity, and to monitor the effects thereof.[242] Article 14 of the CBD, the second relevant commitment, has provisions for three contexts.[243] In terms of domestic effects, Parties are, once again "as far as possible and as appropriate," to require environmental impact assessments for proposed activities that are likely to have significant adverse effects on biological diversity, and to ensure that the impacts are "duly taken into account." In the case of likely significant transboundary impacts, the Parties to the CBD are to promote notification, exchange of information, and consultation, by encouraging multilateral arrangements as appropriate. Finally, if there is grave and imminent danger to biological diversity, Parties should have arrangements for emergency responses and encourage international cooperation. If these dangers are transboundary, then immediate notification and action are required.

The CBD COPs have issued four decisions concerning climate engineering. These are nonbinding on Parties but have been influential.[244] The first, in 2008, was limited to ocean fertilization, under which the COP requested

> Parties and urges other Governments, in accordance with the precautionary approach, to ensure that ocean fertilization activities do not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks, and a global, transparent and effective control and regulatory mechanism is in place for these activities; with the exception of small scale scientific research studies within coastal waters. Such studies should only be authorized if justified by the need to gather specific scientific data, and should also be subject to a thorough prior assessment of the potential impacts of the research studies on the marine environment, and be strictly controlled, and not be used for generating and selling carbon offsets or any other commercial purposes;[245]

Parties expanded this statement two years later to include all climate engineering, albeit in softer language:

> The Conference of the Parties … Invites Parties and other Governments … to consider the guidance below …
>
> Ensure … in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment.[246]

At that time, the COP adopted a tentative definition for geoengineering:

> Any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large scale and that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere).[247]

A later report refined the definition to "a deliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts."[248] Two later decisions by the CBD COP reaffirmed the previous decisions, made general observations, and requested Parties to address gaps in the understanding of the impacts of climate engineering on biodiversity.[249] The most recent one, from 2016, notably called for more research "in order to better understand the impacts of climate-related geoengineering on biodiversity and ecosystem functions and services, socio-economic, cultural and ethical issues and regulatory options."[250]

These decisions by the CBD COP are important, as they represent the only negotiated consensus concerning climate engineering in general (and ocean fertilization specifically) from representatives of most of the world's states. The two substantive statements are ones of concern, calling upon all states to ensure that climate engineering activities of a certain type or scale do not take place until explicit criteria are met. In the case of ocean fertilization, small-scale scientific research studies within coastal waters – a location that ironically would not be scientifically useful – are the only exception. In order for climate engineering in general to be covered by these decisions, the activity must be at a large enough scale that it would affect biodiversity, and an exception is made for "small scale scientific research studies that would be conducted in a controlled setting." Because that final term has not been defined, it remains unclear whether a "controlled setting" is limited to indoor activities or could include low-risk or fairly well-contained outdoor ones. Each decision describes the conditions under which the request for preventing activities would be lifted, and these are highly congruous: There must be an adequate scientific basis, an assessment or consideration of risks, and (science-based) global, transparent, and effective control and regulatory mechanisms. Appropriate assessment procedures prior to a climate engineering activity could satisfy the first two conditions. In contrast, the need for global regulation is a challenging criterion to satisfy. In its 2012 general decision on climate engineering, the CBD COP noted the continued lack of adequate regulation, while reports issued by the CBD Secretariat have acknowledged that ocean fertilization experiments and sub-seabed carbon dioxide storage are "possible exceptions" to this absence and that "[m]any ocean-based potential geoengineering approaches are already covered under the" London Convention and London Protocol."[251]

At the same time, the CBD COP decisions are limited in their effects, legal and otherwise. Most importantly, as COP decisions they are nonbinding. Indeed, reports issued by the CBD Secretariat call the 2010 decision a "non-binding normative framework."[252] Furthermore, the CBD itself and the COP decisions consistently use soft and highly qualified language, and that of the decisions is vague. For example, the 2010 decision concerning "climate-related geo-engineering" in general merely "invites" states to "consider the guidance." That decision's requirement that it be interpreted in accordance with the CBD's Article 14 indicates that the Parties intended the decision to be further limited to activities that are likely to have *significant adverse* effects on biological diversity.[253] Although they are sometimes referred to as moratoria, that is an inaccurate characterization of both their substance and intention. Indeed, the COP explicitly rejected the word "moratorium" in the case of the ocean fertilization decision.[254]

Furthermore, the decisions have also been controversial. A first-hand report of the negotiations toward the 2010 COP decision concluded that "the delegates were not well informed about geoengineering, and negotiations were conducted in haste without proper scientific consideration."[255] Moreover, the ad hoc Consultative Group on Ocean Fertilization of the Intergovernmental Oceanographic Commission of the UN Educational, Scientific and Cultural Organization issued a statement in response to the 2008 CBD COP decision on ocean fertilization. In this, the Group stated that it was "concerned that [the decision] … places unnecessary and undue restriction on legitimate scientific activities," that the limitation of scientific research to coastal waters was "new, arbitrary, and counterproductive … [with] no scientific basis," and that scientific information regarding preservation of marine diversity could be obtained through further research.[256]

As a final note, the CBD Secretariat and Subsidiary Body on Scientific, Technical and Technological Advice have issued a number of reports in order to inform its COPs. The most thorough one was published in 2012, and updated in 2016.[257]

3.3.4.2. Antarctica Treaty System

The continent of Antarctica is the second of three primary areas that are typically considered beyond national jurisdiction, and the area south of 60° latitude is governed by a number of interrelated treaties.[258] Some climate engineering activities could occur there, in either the terrestrial or the marine environments. In particular, the Southern Ocean is a leading location for potential ocean iron fertilization. Furthermore, although SRM would generally be less effective there due to the angle of incoming sunlight and the already high albedo, some researchers are interested in regional SRM as a means to preserve ice sheets.[259] Generally speaking, the treaties concerning Antarctica call upon their Parties both to protect the environment and to conduct scientific research. Unlike UNCLOS, these agreements prioritize neither of these goals over the other, emphasizing a potential tension between them.

The central Antarctic Treaty counts 53 Parties, including the major economic powers, and has been in effect since 1961. It establishes a freedom of scientific investigation – presumably including that of climate engineering research – and encourages international cooperation in this area.[260] At their meetings, Parties are to discuss, inter alia, the facilitation of scientific research and the "preservation and conservation of living resources."[261] All activities in Antarctica must be for peaceful purposes.[262]

The 1991 Protocol on Environmental Protection of the Antarctic Treaty (the Madrid Protocol) further explicates states' commitments, obligations, and rights concerning scientific research and environmental protection in Antarctica. It is in effect, with 33 participating states. All of these goals remain high priorities in the Protocol. For example, in its objective, Parties commit to "the comprehensive protection of the Antarctic" and "designate Antarctica as a natural reserve, devoted to peace and science."[263] Its first principle emphasizes this, providing that both environmental protection and "scientific research, in particular research essential to understanding the global environment" are to be "fundamental considerations in the planning and conduct of all activities."[264] Another principle is that "[a]ctivities shall be planned and conducted so as to accord priority to scientific research … including research essential to understanding the global environment."[265] The upshot of this is that climate engineering activities that would help protect the Antarctic environment and climate engineering research that would be free of adverse environmental impacts are each to be prioritized, but it is unclear how Parties should respond to proposals for climate engineering activities – especially research – that might have adverse impacts.

Regarding their substantive commitments, Parties to the Madrid Protocol are to plan their activities in the Antarctic to limit adverse environmental impacts.[266] This limitation includes avoiding, among other things, "adverse effects on climate or weather patterns; significant adverse effects on air or water quality; significant changes in the atmospheric, terrestrial (including aquatic), glacial or marine environments"; detrimental changes to the populations of plants and animals; putting endangered or threatened species at further risk; and degrading or putting at risk "areas of biological, scientific, historic, aesthetic or wilderness significance."[267] These obligations all emphasize the tension between climate change and climate engineering, which respectively will and might have adverse effects on climate, the environment, species, and significant areas. Furthermore, Parties are to plan their activities in Antarctica based on sufficient information to allow a prior assessment of and informed judgments about the potential impacts on the continent's environment and its value as a site of scientific research.[268] In line with this, Parties must cooperate as well as monitor, assess, and report the environmental impacts of their activities.[269] Scientific research programs are explicitly subject to prior environmental impact assessment. If an activity such as climate engineering "results in the significant adverse modification of habitat," or if a research activity were planned to take place in a "Specially Protected or Managed Area," then a permit from the Party's appropriate regulatory authority would be required.[270] Finally, if ocean fertilization or other marine geoengineering were to introduce substances into the sea "in quantities or concentrations that are harmful to the marine environment," then it would be prohibited, although noncommercial government ships are exempt from this prohibition.[271]

3.3.4.3. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques

The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) was completed in 1976 in order to end the use of weather modification techniques in warfare and other hostile situations. It is now in effect through the participation of its 77 Parties, which include almost all major industrialized states.[272] It is highly relevant to climate engineering because its definition of "environmental modification" clearly encompasses almost all climate engineering proposals.[273]

Centrally, the ENMOD Parties agree "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party."[274] That is, prohibition requires meeting three criteria: to be military or hostile, to satisfy one of three criteria of scale, and to directly harm another ENMOD Party. The trio "widespread, long lasting or severe," which was later used in the amendment to the London Protocol regarding marine geoengineering, is not defined in ENMOD itself but was in a nonbinding Understanding thereto. This Understanding describes them as:

> "widespread": encompassing an area on the scale of several hundred square kilometres; "long lasting": lasting for a period of months, or approximately a season; "severe": involving serious or significant disruption or harm to human life, natural and economic resources or other assets.[275]

The first two criteria of scale can be determined somewhat objectively, and climate engineering large-scale field research projects or implementation would most likely satisfy them. The criterion of severity, which notably is limited to life, resources, and assets, is less certain.

Simultaneously, ENMOD recognizes and is rhetorically supportive of peaceful environmental modification. The agreement explicitly "shall not hinder the use of environmental modification techniques for peaceful purposes."[276] Furthermore, in its Preamble, Parties recognize "that the use of environmental modification techniques for peaceful purposes could improve the interrelationship of man and nature and contribute to the preservation and improvement of the environment for the benefit of present and future generations."[277] To that end, Parties are to facilitate the exchange of information regarding such peaceful uses, and those Parties "in a position to do so shall contribute … to international economic and scientific co-operation in the preservation, improvement and peaceful utilization of the environment."[278] If climate engineering is able to counter climate change risks, then it would be such "preservation, improvement and peaceful utilization," and Parties with the capacity to do so are obligated to contribute to cooperation.

A challenge to the implementation and enforcement of ENMOD is its weak institutional support. It has neither a standing secretariat nor regular meetings of its Parties. Such meetings are infrequently proposed. The ENMOD Parties have held two meetings, but declined to do so again in 2013.[279] If the Parties were to choose to do so, a meeting could provide a potential institutional vehicle to clarify the relationship among climate engineering, international law, and the preferences of much of the international community.

3.4. OTHER DOMAINS OF INTERNATIONAL LAW

3.4.1. *Civil Aviation*

Some climate engineering techniques, such as stratospheric aerosol injection and cirrus cloud thinning, could be researched or implemented using aircraft, which would emit particular substances. States would need to comply with international aviation law, which governs the international aspects of such vehicles. The central multilateral agreement, the Convention on International Civil Aviation (the Chicago Convention), grants sovereignty to Parties over their airspace and enjoys global participation.[280] This airspace extends upward from their territory – from both land and territorial waters – to the undefined upper border with outer space.[281] Parties are to ensure that aircraft bear a nationality mark and comply with other standards, and under a related treaty, the state of registration can exercise jurisdiction over aircraft.[282] States are to permit unscheduled flights through their airspace provided that the foreign aircraft are not military, customs, or police aircraft, and that the aircraft operate with a purpose consistent with the aims of the Chicago Convention.[283] Scheduled flights as well as pilotless, military, customs, and police aircraft require prior authorization.[284] Flights over the high seas must also follow the Convention's rules.[285]

Regarding aircraft emissions, which would presumably include substances intentionally injected into the atmosphere for climate engineering, Parties may establish their own regulations for all aircraft operating in their territory, as long as these rules are enforced without distinction to the aircraft's country of registration.[286] However, Parties are expected the keep the rules relatively uniform and consistent with guidelines established by the International Civil Aviation Organization (ICAO), a UN body established by the Chicago Convention.[287] Deviations from the ICAO guidelines are to be reported by Parties.[288] The ICAO has guidelines regarding specific pollutants from aircraft emissions, but these do not address materials such as sulfates that are presently considered for climate engineering purposes.[289] Therefore, atmospheric climate engineering – even in the airspace of countries other than that of the aircraft's nation of registry – appears at first glance to be compliant with international aviation law. However, the state in whose airspace the climate engineering activity occurred could assert that such flights are inconsistent with the aims of the Chicago Convention or that they are contrary to other international law.[290]

If a Party has reasonable grounds to believe that an aircraft in its territory is being used for purposes inconsistent with Convention's aims, then it may require that the aircraft land and take any appropriate means that are consistent with international law, as well as giving instructions that any such violations must cease.[291] Under certain circumstances – including to ensure compliance with any other treaty – a state may "interfere with" an aircraft in the case of a criminal offense.[292] Parties are to take steps to ensure that aircraft in their territory comply with these requests, and that they do not use their own aircraft for purposes inconsistent with the aims of the Chicago Convention.[293] Disputes between Parties that negotiation cannot resolve may be submitted to the ICAO Council.[294]

3.4.2. *Space Law*

SRM climate engineering could, at least in principle, be done in outer space, by placing objects in orbit or at the L1 Lagrangian point between the Earth and the Sun.[295] Although these proposals presently appear to be prohibitively expensive, this might not always be the case. States' activities in outer space, an area that remains undefined, are governed by a set of multilateral agreements. The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty) is foundational, and counts as Parties all states with space programs. In it, Parties are to conduct space activities "for the benefit and in the interests of all countries … in accordance with international law … in the interest of maintaining international peace and security and promoting international cooperation and understanding" and "with due regard to the corresponding interests of all other States Parties."[296] Parties are to inform the UN, the international scientific community, and the public as to their space activities and the results thereof.[297] All space activities must be conducted or authorized by the Party's government, and the Party is responsible for those activities.[298] The Treaty established a "freedom of scientific investigation in outer space," and Parties should facilitate and encourage cooperation in carrying out research.[299] These commitments would apply to climate engineering activities in space.

The most interesting – and perhaps most relevant – provisions under space law are those regarding liability for harm from space activities. The Outer

Space Treaty establishes, and the Convention on International Liability for Damage Caused by Space Objects details the liability provisions. Under these, the Party (or Parties) that launches, procures the launching, or provides the launching site has absolute liability (i.e., with no need to demonstrate fault) for damage from their space objects to other Parties in outer space, in the atmosphere, and on the Earth.[300] Multiple liable Parties are jointly and severally liable.[301] This liability implicitly includes harm from accidents as well as from expected operations, and from direct contact as well as from remote effects. Therefore, space-based SRM is the only suggested climate engineering technique under which the state that undertakes or authorizes it would clearly be liable for transboundary harm through a treaty's provisions.

3.4.3. *Human Rights*

Human rights law might be a somewhat ambiguous domain of international law with respect to climate engineering, but it can provide guidance as to how states and even private actors should proceed with climate engineering research, development, and possible implementation. Human rights may shape large-scale outdoor climate engineering activities, scientists' conduct of research, people's enjoyment of the benefits of scientific research, and decision-making procedures.

Before going forward, some clarification may be helpful. Human rights are a subcategory of rights – that is, claims of entitlement by someone to something from someone else – that all people have by the mere fact of being human. The duty bearers of human rights are usually, but not always, states, which have committed themselves to ensuring human rights through a series of binding and nonbinding international legal instruments. So-called first-generation or negative human rights are political and civil rights such as those to life (i.e., to not be arbitrarily deprived of one's life), to equality before the law, and to freedom of thought, conscience, and religion. States generally have duties to ensure that people within their territory and subject to their jurisdiction can enjoy these rights. Second-generation or positive human rights are economic, social, and cultural rights such as those to food, housing, the highest attainable standard of health, education, and participation in cultural life. States have progressive duties first to respect the right by not directly interfering with its enjoyment, second to protect it by preventing third parties from interfering with its enjoyment, and third to fulfill it by taking action toward its full realization.[302]

In the case of large-scale outdoor climate engineering activities, interpretation of human rights could point in contradictory directions depending upon the circumstances. If the field research or implementation of particular climate engineering proposals were expected to have environmental impacts severe enough to threaten inter alia the availability of food, housing, and standards of health for a state's population, then carrying out these activities might undermine human rights. For example, BECCS is a CDR technique that the IPCC's more optimistic scenarios assume will be implemented at very large scales, requiring very large areas of arable land. The resulting competition for land could cause food prices to increase, which could put at risk the right to food.[303] Whether this would actually be the case would depend on factors including the impact on food prices, the magnitude of this price impact on people's ability to access food, the strength of the climate engineering activity's causal effect on food prices, and the climate change risks – particularly to food production – that the CDR activities prevented or reduced. Under circumstances in which the threat to a second-generation human right – such as that to food – is clear, states would be obligated to respect the right by not undertaking the climate engineering activity themselves and to protect the right by trying to prevent others from doing so. On the other hand, if the existing evidence was that certain forms of climate engineering research or implementation could greatly reduce grave climate risks, then the state might arguably have a duty to authorize, encourage, or undertake these activities in order to fulfill rights such as those to food, housing, and the highest attainable standard of health.[304] Given the complexities of climate change and of climate engineering, as well as the diversity of the conditions and interests of the human race, climate engineering is likely to have the capacity to undermine the human rights of some people, while fulfilling those of others. The uncertainty of actual outcomes from climate engineering further exacerbates this challenge.

Scientific research is the object of human rights as well. Some writers assert that academic freedom is a human right based upon the rights to freedom of opinion and expression, to an education, and to freedom of scientific research and creative activity.[305] Any such academic or scientific freedom would be subject to balancing with and constraints from other fundamental rights, funding, safety, research subjects' rights, and environmental harm. An additional human right of scientists is the protection of their "moral and material interests" from their research activities.[306] This indicates a duty of states to progressively realize inventors' rights to benefit from their work, for which patents are the leading vehicle. Thus, states are to respect this right by refraining from infringing upon patents themselves, to protect it by preventing infringement by third parties, and to fulfill it by implementing laws and administrative regulations that award and defend patents. Again, this should be done with due consideration for potentially conflicting legitimate interests such as other human rights.

International law also provides for a human right to enjoy the benefits of scientific research. In fact, enjoying these benefits may be a precursor to the fulfillment of other human rights such as those to life, food, and health. A Special Rapporteur to the UN Human Rights Council describes the right to enjoy the benefits of scientific progress as having four normative tenets.[307] First, everyone should be able to access science's benefits, without discrimination. In the case of climate engineering, this indicates that governments should ensure that data, results, publications, and materials are freely available, such as through data repositories and open access publication, in a nondiscriminatory manner. Second, everyone should have the opportunity to contribute to scientific research. This tenet is roughly congruous with freedom of scientific research, described above. Third, people have a right to participate in science-related decision-making, particularly regarding setting major research priorities and policies. Here, states should provide their residents and citizens with such opportunities to participate in relevant decision-making concerning climate engineering research. Fourth, states should ensure the conservation, development and diffusion of science and technology. In particular, industrialized countries should internationally collaborate in scientific research, and should prioritize technologies that would be of the greatest benefit to poor and otherwise marginalized people. This implies that they should support research intro climate engineering methods that could reduce climate risks to vulnerable populations, and that developing countries should take steps toward the appropriate development, importation and dissemination of those climate engineering technologies that may assist their own residents and citizens.

Procedural rights are also sometimes considered among human rights. For example, populations that are likely to be affected by climate engineering might have the rights to be notified, to access relevant information, to participate in decision-making processes, and to have access to the appropriate administrative and judicial processes, especially in seeking remedies for harm.[308] Both the Universal Declaration of Human Rights and the International Covenant on Civil and Political Rights might have established a right to access information.[309] However, participation in decision-making in environmental matters is not consistently recognized as a human right per se. Instead, particular legal instruments such as the Aarhus Convention and the customary international law of transboundary harm advance the participatory right of potentially affected publics.[310] Regardless, the large, if not global scale of climate engineering's effects complicates procedural rights. This would particularly be the case if the "affected public" were to include those whom climate engineering would affect in nonphysical ways.

Finally, because law that is specific to climate engineering is largely absent, private actors could play important roles in ensuring that research proceeds in a manner that is consistent with human rights. For example, professional societies, funders, publishers, and scholars could develop and promulgate codes of conduct that are informed by international human rights law.[311]

3.4.4. *Intellectual Property*

In general, countries promote innovation and new technologies through laws that grant inventors temporary exclusive rights to use their inventions.[312] This intellectual property law is primarily a national matter, but is harmonized through a number of multilateral agreements and international institutions, especially the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) of the World Trade Organization. At least three particular issues arise for possible climate engineering technologies and inventions.[313] First, given the stakes of climate risks, a patent for a climate engineering invention might be essential for the protection of humans and the environment, yet the patent holder might fail to utilize or license the patent, or might demand excessive licensing terms. If so, states may intervene and, for example, compel the patent holder to license the invention on reasonable terms. TRIPS permits such compulsory licensing pursuant to procedural limitations.[314] Second, some people consider some climate engineering methods to be objectionable or unacceptably risky. Under TRIPS, if a particular climate engineering technique were shown to put at risk "*ordre public* or morality, including to protect human, animal or plant life or health or to avoid serious prejudice to the environment," then a state may exclude it from patentability.[315] Third, holders of actual or potentially valuable patents might attempt to influence public bodies' decision-making regarding climate engineering. This concern might warrant special measures.

Regardless, international policy will remain the purview of domestic law and possibly innovative arrangements by private actors.

3.4.5. *International Disputes*

States sometimes disagree, and might do so over climate engineering. Most often, they resolve their disputes through nonlegal and political means. Dispute resolution occasionally moves to more legalized approaches, such as negotiation, mediation, and arbitration. Some multilateral agreements have specialized mechanisms, such as compulsory arbitration or dedicated special tribunals, to try to resolve disputes within their scope. Four international legal fora have much broader ranges of issues that they can address. First, the UN General Assembly has universal participation and can consider almost any matter, but its resolutions are nonbinding.[316] Second, the UN Security Council is limited to the "maintenance of international peace and security," which could include climate engineering activities if they were to greatly raise international tensions. The Security Council can issue legally binding, majoritarian resolutions, although five of the world's most powerful countries have veto power.[317] Even if it can agree on a binding resolution, any enforcement such as sanctions or military action must be performed by one or more willing states. Third, the International Court of Justice can resolve international disputes. However, in order for its rulings in contentious issues to be legally binding, each state must consent to the jurisdiction of the court prior to the trial.[318] By majority vote of the UN General Assembly, a legal question can be referred to the International Court of Justice (ICJ) for an advisory opinion; such an opinion could speak to the obligations of states that have not consented to the ICJ's jurisdiction for such matters, but it would not be binding on them. Finally, states may submit a dispute to the Permanent Court of Arbitration (PCA). However, it lacks standing judges and is thus better considered as an institution for facilitating arbitration. After years of little to no activity, states have been turning to the PCA, perhaps due to its confidentiality, lack of precedent-setting, and generally faster resolution.

3.5. NONBINDING MULTILATERAL ENVIRONMENTAL AGREEMENTS AND INTERGOVERNMENTAL INSTITUTIONS

Although the phrase "international law" generally refers to those instruments, either explicit agreements or custom, that are intended to be legally binding, nonbinding multilateral agreements and the role played by intergovernmental institutions are also important. These agreements can influence the behavior of states that wish to avoid any potential reputational costs that might result from acting contrary to a nonbinding agreement or the advice of an authoritative intergovernmental body. Furthermore, nonbinding agreements and the decisions of intergovernmental institutions often provide a sense of the preferences, norms, aspirations, and interests of various states and of the international community as a whole. They can also establish initial terms for future negotiations toward binding agreements. Some of them can trigger certain obligations under domestic laws, such as reporting requirements. International institutions can play essential coordinating roles. Their authority often derives both from their intergovernmental character and from the expertise – often scientific or technical – of their decision-makers.

A handful of nonbinding multilateral legal instruments and intergovernmental institutions' decisions and reports might have a bearing on the future governance of climate engineering. Particular attention is given here to those nonbinding agreements that have been globally endorsed, or nearly so. Given that these agreements, by their nature, use vague and hortatory language, inferring what they might mean for climate engineering is a subjective practice.

3.5.1. *UN Environmental Summits*

A series of UN-organized global summits on the environment and development have shaped the principles of international environmental. The first two – held in Stockholm in 1972 and Rio de Janeiro in 1992 – are the most significant.

3.5.1.1. Declaration of the UN Conference on the Human Environment

Contemporary international environmental law arguably began with the 1972 UN Conference on the Human Environment, which 113 states attended in Stockholm. The resulting Declaration contains proclamations and principles that sound decidedly anthropocentric to twenty-first-century ears, and that regularly refer to the benefits of improving nature. Therefore, to the extent that the Stockholm Declaration still reflects states' preferences regarding international environmental law, it generally supports interventions in the natural world to improve humanity's well-being.

For example, its purpose is to

> "inspire and guide the peoples of the world in the preservation and enhancement of the human environment," and it proclaims that "[i]n our time, man's capability to transform his surroundings, if used wisely, can bring to all peoples the benefits of development and the opportunity to enhance the quality of life … For the purpose of attaining freedom in the world of nature, man must use knowledge to build, in collaboration with nature, a better environment."[319]

The anthropocentric tone continues in the principles, the first of which includes the assertion that humanity "bears a solemn responsibility to protect and improve the environment for present and future generations."[320] Consistent with this, science and technology are to be "applied to the identification, avoidance and control of environmental risks and the solution of environmental problems and for the common good of mankind."[321] The Declaration also calls for the minimization of transboundary harm and for international cooperation in protecting and improving the environment.[322]

3.5.1.2. Rio Declaration on Environment and Development

Twenty years after the Stockholm Conference and Declaration, the UN hosted the Conference on Environment and Development in Rio de Janeiro. The resulting Declaration, which the UN General Assembly later endorsed, reflects how the priorities of the international community had changed since Stockholm.[323] It gives greater, albeit qualified, emphasis to the protection of natural world itself and it elevates the importance of economic development of poorer countries. These environmental and economic goals are often folded together under the rubric of sustainable development. The implications of the Rio Declaration for climate engineering are less certain compared with those of the Stockholm Declaration. Climate engineering could help protect the natural world from climate change and enable greater economic development, and it could cause significant harm to the environment and to vulnerable populations.

Some anthropocentrism remains: The first sentence of the first principle is "Human beings are at the centre of concerns for sustainable development."[324] Furthermore, the Rio Declaration refers to only two rights: that of states' "sovereign right to exploit their own resources pursuant to their own environmental and developmental policies" (coupled with their responsibility to prevent transboundary harm), and a right to development, which remains undefined.[325] To the extent that the latter right indeed exists in international law, then climate engineering might help enable it, given that climate change risks will be disproportionately borne by poor states and that GHG emissions and economic development remain coupled.

More specifically, the Rio Declaration calls for "improving scientific understanding" and for developing "new and innovative technologies."[326] In one of its principles, states are to avoid transferring sources of environmental harm to other states.[327] If climate engineering merely moved the location of climate risks, it would violate this principle. Finally, the Rio Declaration reiterates a number of procedural duties, such as states' obligations to conduct environmental impact assessments, notify potentially affected states, and provide public access to information, as well as several principles of international environmental law, including common but differentiated responsibilities, precaution, polluter pays, intergenerational equity, cooperation, and sustainable development.[328]

3.5.1.3. From the Johannesburg Declaration to Sustainable Development Goals

The UN organized further summits on sustainable development in Johannesburg in 2002 and again in Rio de Janeiro in 2012. Instead of a couple dozen new, clarified, or expanded principles, their reports offer long lists of recognitions, aspirations, and goals. These serve mostly to reaffirm and, by their nature, add little to international environmental law.[329] The report from the 2012 summit, *The Future We Want*, reads like a "laundry list" of nearly 300 such goals. Notably, one of these expresses concern about the potential negative environmental impacts of ocean fertilization.[330]

The UN Member States agreed at the 2012 summit to establish a working group to develop a new set of overarching goals to replace the UN Millennium Development Goals, which had established targets for 2015. The UN General Assembly approved the resulting 17 Sustainable Development Goals in September 2015.[331] In turn, these goals consist of 169 targets to be reached by 2030. Combating climate change not only has its own goal, but is also integrated into several others and is emphasized in the Preamble. Three months later, the Paris Agreement incorporated much of the Sustainable Development Goals' climate-specific language.

Few implications specific to climate engineering can be gleaned from the Sustainable Development Goals. Their Preamble does "note with grave concern the significant gap between … Parties' mitigation pledges … and … having a likely chance of holding the increase in global average temperature below 2°C or 1.5°C," implying a potential important role for CDR.[332] Further, human and institutional capacity is to be improved on, among other things, reducing the impacts of climate change.[333] One could argue that SRM is a means to reduce climate impacts. Finally, the combination of the climate goal with others, such as ending poverty, achieving food security, and sustainable development more generally, imply that climate change risks must be reduced rapidly and at low cost.

3.5.2. *UN Environment Programme*

Since its launch soon after the 1972 Stockholm Conference, the UN Environment Programme (UNEP) has played an important role in coordinating other international bodies and national governments, and in laying the foundation for the development of international environmental law. Examples are given below.

3.5.2.1. UNEP Provisions for Co-operation between States in Weather Modification

In 1980 UNEP approved Provisions for Co-operation between States in Weather Modification, in cooperation with the World Meteorological Organization

(WMO). As in ENMOD, the term "weather modification" is defined in a manner that would include SRM climate engineering, and perhaps CDR methods as well.[334] Also like ENMOD, it is generally supportive of states' use of weather modification in appropriate circumstances, in this case for "the benefit of mankind and the environment."[335] To this end, "States should encourage and facilitate international co-operation in weather modification activities, including research."[336] As its name implies, the document calls on states to cooperate through, for example, information exchange, notification, and consultation.[337] States are to collect relevant information regarding their weather modification activities and to share it with the WMO.[338] Finally, they are further encouraged in the document to undertake prior environmental assessment of their weather modification activities that might have transboundary impacts, and to conduct those activities in a manner that prevents environmental damage in other countries or in areas beyond national jurisdiction.[339] Note that only the UNEP Governing Council, which has 58 states as members, approved the Provisions.

3.5.2.2. Recent Activity

UNEP has demonstrated some institutional interest in climate engineering in recent years. It supported a workshop led by the UN Education, Social and Cultural Organization (UNESCO), described below. Along with the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the WMO, UNEP cosponsored a 2011 International Scientific Conference on Problems of Adaptation to Climate Change, hosted by the Russian Academy of Sciences. There, climate engineering was among the topics discussed.[340]

3.5.3. *UN Education, Social and Cultural Organization*

UNESCO is a UN specialized agency with the mandate to promote international collaboration in the domains of education, science, and culture. It hosted an expert meeting on climate engineering in 2010.[341] The 20 participants recommended an international research program modeled on the World Climate Research Programme.[342] This would be sponsored by UNESCO, the IOC, the International Council for Science, and the WMO, and "could address the technological and scientific challenges of geoengineering and ensure that legitimate scientific research into this controversial issue may proceed."[343] A policy brief was later published, which bore the endorsements of UNEP and the Scientific Committee on Problems of the Environment.[344]

The IOC of UNESCO commissioned a report on ocean fertilization.[345] The Surface Ocean Lower Atmosphere Study helped prepare it, and the International Geosphere-Biosphere Programme, the Scientific Committee on Oceanic Research, the World Climate Research Programme, and the International Commission on Atmospheric Chemistry and Global Pollution sponsored it. The IOC issued the report in 2010.

3.5.4. *World Meteorological Organization*

The WMO is a UN agency that fosters international coordination and cooperation in diverse issues of weather and climate, including the atmosphere, oceans, and water resources. The WMO was referenced above in the contexts of the 1980 UNEP Provisions for Co-operation between States in Weather Modification and the 2010 UNESCO expert meeting. Under the guidance of its Expert Team on Weather Modification, the WMO also appears to be in the process of developing a statement on climate engineering. The draft statement "closely follows" the previous such statement from the American Meteorological Society.[346] The most recent plan within the WMO is for its Commission for Atmospheric Sciences to work toward an assessment of climate engineering, in cooperation with the World Climate Research Programme, the IOC of UNESCO, the IMO, and others.[347]

3.5.5. *The Intergovernmental Panel on Climate Change*

UNEP and the WMO established the IPCC in 1988 in order to assess the state of climate change knowledge, the impacts of climate change, and possible response strategies. Its primary output has been the occasional publication of comprehensive assessment reports, which collect and summarize the most recent scientific information. Beginning with the Third Assessment Report, published in 2001, these have devoted limited – but increasing – attention to climate engineering. The most recent Fifth Assessment Report considers climate engineering methods in a number of contexts. It concluded, for example, that:

> Several CDR techniques could potentially reduce atmospheric greenhouse gas (GHG) levels. However, there are biogeochemical, technical and societal limitations that, to varying degrees, make it difficult to provide quantitative estimates of the potential for CDR …
>
> SRM is untested, and is not included in any of the mitigation scenarios, but, if realisable, could to some degree offset global temperature rise and some of its effects. It could possibly provide rapid cooling in comparison to CO_2 mitigation …

> SRM technologies raise questions about costs, risks, governance and ethical implications of development and deployment. There are special challenges emerging for international institutions and mechanisms that could coordinate research and possibly restrain testing and deployment.[348]

In 2011 the IPCC convened an expert meeting on climate engineering, and later published a meeting report.[349]

3.5.6. *UN General Assembly Resolution on Oceans and the Law of the Sea*

In 2007 the UN General Assembly approved a Resolution containing a passage relating to climate engineering. The Resolution on Oceans and the Law of the Sea urged states to exercise caution when considering proposals for ocean fertilization.[350] It further stated that, while large-scale ocean fertilization activities were not justified at that time, states should encourage research in that area.[351]

3.6. CUSTOMARY INTERNATIONAL LAW

Customary international law is a set of legally binding rules derived from states' repeated behavior and evidence that they do so out of a sense of legal requirement. Because it is not centrally transcribed, the precise obligations that customary international law imposes upon states are often somewhat unclear. Nevertheless, it provides an essential gap-filling function, preventing, resolving, and governing international disputes over environmental rights and duties in the absence of a specific multilateral agreement. Three domains of customary international law will be relevant for climate engineering: the right to exploit natural resources, the duty to prevent transboundary harm, and state responsibility for harm. This section also discusses a new document that attempts to gather together existing custom regarding the atmosphere.

3.6.1. *Sovereign Right to Exploit Natural Resources*

If sovereignty is the foundation of international relations and international law, then states' sovereign right to exploit their own natural resources is one of the two cornerstones of international environmental law. In theory, this right could be considered an implicit default condition within the system of sovereign states, at least prior to the rise of environmental law in the twentieth century.[352] Developing countries that were asserting their independence in the wake of decolonization made the right for a state to exploit its natural resources explicit. This right was initially recognized globally, beginning with

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the 1952 UN General Assembly Resolution on the Right to Exploit Freely Natural Wealth and Resources and the 1962 Declaration on Permanent Sovereignty over Natural Resources.[353] Within international environmental law, many (if not most) multilateral agreements, beginning with the 1972 Stockholm Declaration, provide for or restate it.[354] The implication of this tenet of customary international law is that states have a presumptive right to conduct climate engineering activities within their own territory, provided that they do so in a manner consistent with their other rights and obligations.

3.6.2. *Prevention of Transboundary Environmental Harm*

The second of the two cornerstones of international environmental law is that states have a responsibility to prevent transboundary environmental harm – including that to areas beyond the limits of national jurisdiction – arising from activities within their jurisdiction or under their control. Such transboundary harm may occur due to outdoor climate engineering activities of sufficient scales. Although this responsibility arose in the early twentieth century distinct from and in parallel with the sovereign right to exploit natural resources, the two fused in the 1972 Stockholm Declaration and since then have generally been presented as two sides of a single coin.[355] Many multilateral environmental agreements reiterate this responsibility.[356] In 1996 the International Court of Justice stated that the responsibility is part of customary international law,[357] citing a principle of the Rio Declaration, in which

> States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.[358]

This responsibility is not an inviolable obligation to ensure that absolutely no transboundary environmental harm occurs. Instead, the objective is the prevention of transboundary harm, while the obligation of states is one of practicing due diligence regarding activities, such as outdoor climate engineering activities, that occur within their jurisdiction or control and that pose a risk of significant transboundary harm.[359] The due diligence standard is roughly proportional to the probability and the magnitude of the risk. In its Draft Articles on the Prevention of Transboundary Harm from Hazardous Activities, the ILC of the UN attempted to clarify the responsibilities based upon state practice and the rulings of international tribunals. It concluded that the responsibility to prevent transboundary harm arises when an activity could pose a "risk of causing significant transboundary harm through their physical consequences … [including] risks taking the form of a high probability of causing significant transboundary harm and a low probability of causing disastrous transboundary harm."[360] Each of these two formulations of risky activities could apply to various suggested climate engineering activities. Once that threshold has been met, states must undertake "all appropriate measures" to prevent the potential harm and to reduce its risk. These measures include requiring authorization for the activity, performing an environmental impact assessment, notifying and cooperating in good faith with potentially affected states, informing the public, and developing contingency plans for an emergency.[361] The precise steps are subject to consultations between the countries, and are to be "based on an equitable balance of interests."[362] Factors to consider in this balancing of interests include:

> the importance of the activity, taking into account its overall advantages of a social, economic and technical character for the State of origin in relation to the potential harm for the State likely to be affected; … [and] the economic viability of the activity in relation to the costs of prevention and to the possibility of carrying out the activity elsewhere or by other means or replacing it with an alternative activity.[363]

A balancing of interests should thus take into account both the benefits and risks of the proposed climate engineering activity for all concerned states.[364] An activity that posed great risk to another state with little likely benefit for the state of origin would be interpreted quite differently than a modest, low-risk one undertaken by a state whose great risks from climate change could subsequently be lowered through the proposed climate engineering activity. If the consultations fail to produce a consensus among the states, then the state of origin is to take into account the interests of potentially affected states in its decisions, such as whether to authorize the activity.[365]

Because large-scale outdoor climate engineering activities could pose risks of transboundary impacts, the state of jurisdiction or control is obligated to undertake these procedural duties. Beyond that, scholars have divergent opinions as to the potential of these customary responsibilities to regulate the risks of climate engineering effectively. Reichwein and coauthors argue that the risk of abrupt termination of SRM is great enough that due diligence may call for SRM not to be implemented in the first place.[366] However, this conclusion requires that sudden termination has a high risk probability, which is not self-evident. Furthermore, the responsibility to prevent transboundary harm requires states to comply with certain procedural duties and, in the absence of consensus, to take other states' interests into account. Customary international law does not prohibit activities that are known to cause transboundary harm. In fact, a passage was removed from a previous version of the ILC's articles that said that the state of origin shall refuse authorization of an activity that would cause unavoidable transboundary harm.[367] Reichwein and coauthors, as well as Bodansky, cite the difficulty in demonstrating specific risks with sufficient confidence as a barrier to the regulatory effectiveness of the customary international law regarding transboundary harm.[368] Elsewhere, Bodansky highlights the challenges and likely controversy in interpreting this responsibility in the case of climate engineering, given that climate engineering itself is intended to prevent transboundary harm.[369]

A final, unexplored question is whether the responsibility to prevent transboundary harm could be interpreted as obligating states to research, or even implement climate engineering, if it is found to be effective and without undue adverse impacts. Because all states emit GHGs, this customary responsibility obligates them to adopt, implement, and enforce policies that aim to abate their GHG emissions.[370] Countries, especially those with greater emissions, might bear an analogous responsibility to enact policies to consider reducing their transboundary harm of climate change through the research – and perhaps implementation – of climate engineering.

3.6.3. *State Responsibility and Liability*

Customary international law also has provisions regarding how states should respond to acts that have caused transboundary harm, including environmental damage that could result from climate engineering activities. Although these provisions are less well developed than those concerning the prevention of transboundary harm, the ILC has tried to capture them in two documents. The division between responsibility for acts that are contrary to international law and compensation for transboundary harm from hazardous activities that are consistent with international law has been useful, in large part because the legal status of the latter group – which arguably does not reflect customary international law – is contested.

As described in the ILC Draft Articles on Responsibility of States for Internationally Wrongful Acts, a state's action or omission is wrongful if it breaches international law and is attributable to the state.[371] Regarding the latter criterion, the Draft Articles focus on whether the actor who actually undertook or authorized the action is part of "the state" or not. In a somewhat different vein, in the context of climate engineering, some writers have expressed concern that the doctrine of state responsibility would require the attribution of specific environmental harms to particular climate engineering activities, which would be a challenging endeavor.[372] However, many (if not most) of the obligations in international environmental law are ex ante procedural duties that countries should or must carry out prior to a risky activity. A state that failed to comply with these obligations is still responsible, independent of any ex post manifestation of harm. However, demands for reparation by an injured state, discussed immediately below, do require injuries that can be attributed to the state's wrongful acts.

If a state has committed a wrongful act, it should cease the activity, assure that the act will not recur, and make full reparations for any injuries.[373] Reparations can take the form of restitution (reestablishing the situation that existed before the wrongful act), compensation (providing something of value, usually money, to compensate for the harm), and satisfaction ("an acknowledgement of the breach, an expression of regret, a formal apology, or another appropriate modality"), in that order of priority.[374] Restitution is often difficult for environmental damage. Thus, states are generally liable for compensation from transboundary harm that results from their legally wrongful acts, including failing to follow due diligence in preventing transboundary harm.[375] Although under the ILC Draft Articles reparations extend to injury, including material and moral, compensation is limited to "financially assessable damage."[376]

States face certain additional consequences if they engage in a "serious breach" of a peremptory norm of international law.[377] A serious breach is one that "involves a gross or systematic failure" of obligations.[378] A peremptory norm (or *jus cogens*) is a fundamental, core value of the international order, one from which no violation is permitted. Unlike other tenets of customary international law, countries are automatically bound by peremptory norms and therefore may not ratify treaties that are contrary to them. There is no definitive list of peremptory norms, but they typically include only the most egregious activities such as genocide, slavery, and crimes against humanity. The ILC declined to list them in the final version of its Draft Articles. A draft version 25 years earlier described an analogous category, that of "international crime," which included "a serious breach of an international obligation of essential importance for the safeguarding and preservation of the human environment, such as those prohibiting massive pollution of the atmosphere or of the seas."[379] The fact that the ILC removed this provision and the absence of the relevant state practice imply that "massive pollution of the atmosphere" would likely not violate peremptory norms of international law. At the same time, the possibility that maintaining the planet's climate might be regarded as a peremptory norm, and that a state's failure to prevent, reduce, and control GHG emissions and/or harmful climate engineering should not be completely ruled out.[380]

The ILC Draft Articles also describe under what circumstances acts contrary to international law should not be considered wrongful. Among these is necessity, under which a state's action is not wrongful if it is the only means for the state "to safeguard an essential interest against a grave and imminent peril," and if it does not put the essential interests of other states at risk.[381] The ICJ has ruled that grave and imminent environmental risks can constitute a state of necessity.[382] For countries such as small island states that could face existential risks from climate change, necessity might operate as a legal preclusion from wrongfulness for climate engineering activities that would otherwise be contrary to international law. However, a state may not invoke necessity if it has contributed to the situation that gave rise to the necessity.[383] All countries have emitted GHGs, which are the cause of climate change and its risks, and have thus all contributed to the state of necessity. At the same time, historical contributions to anthropogenic GHG emissions and policies to control them vary dramatically among countries, and those countries with very low historical emissions or aggressive emissions abatement policies might be able to successfully invoke the necessity defense for climate engineering activities that would otherwise breach international law.

As with other international environmental legal instruments, climate engineering must be considered in the context of the likely environmental harm from climate change. States might have committed wrongful acts, such as failing to adopt effective GHG emissions abatement policies in contravention of the UNFCCC, its Kyoto Protocol, its Paris Agreement, or the customary responsibility to prevent transboundary harm. In this context where GHG abatement failure is the wrongful act, climate engineering could have two roles pursuant to the customary law of responsibility, one for the responsible state and one for the injured state. Regarding the former, as described above, states that are responsible for a wrongful act must, among other things, cease the activity and make reparations to the injured states. Climate engineering could contribute to fulfilling these obligations. If CDR were to reduce a responsible state's annual net emissions to zero, then it would arguably have stopped its wrongful activity. Furthermore, although restitution of diffuse environmental damage, including that from climate change, is typically difficult, climate engineering might be able to contribute to this. For example, large-scale CDR might restore the atmosphere to its former condition by counteracting a country's historical GHG emissions. Furthermore, if SRM climate engineering could be implemented safely and with climatic impacts consistent with current models, then it could help restore the climate, including offsetting effects that might injure affected states.

Injured states, by contrast, have a right to undertake countermeasures. These are acts that are otherwise contrary to international law that are directed at the responsible state in order to induce it to comply.[384] Countermeasures can be taken by an injured state in response to a typical breach, or by any state in response to a breach of an obligation that is owed to the international community as a whole.[385] Considering that the UNFCCC recognizes the prevention of climate change as a common concern of humanity, the latter may indeed be the case.[386] Therefore, in this scenario a state might be able to carry out or authorize climate engineering activities that would otherwise be contrary to international law as a countermeasure. In particular, SRM could be effective in this context due to its high leverage, speed of action, and the reversibility of its direct climatic effects. Countermeasures are subject to several somewhat strict limitations. Before taking them, the injured state must provide the responsible state with the opportunity to fulfill its obligations. If the latter then fails to do so, the injured state must notify the responsible state of any intentions to perform countermeasures.[387] Countermeasures must be proportionate to the injury suffered, and may not be among certain prohibited acts, such as the use of force or violations of fundamental human rights.[388] The countermeasure must end as soon as the responsible state has ceased its wrongful activity, made sufficient assurances that the activity will not recur, and provided full reparations to the injured states.[389] One significant legal barrier to the use of climate engineering as a countermeasure in response to states' failure to abate GHG emissions is that "[a]n injured State may only take countermeasures against a State which is responsible."[390] Citing a ruling of the ICJ, the accompanying commentary of the ILC Draft Articles clarifies that the injured state may act in a manner that is otherwise contrary to international law with respect to *only* the responsible state; other states' rights under international law may not be violated.[391] On the one hand, SRM as it is presently understood, could be global or perhaps regional in its effect, and would consequently serve poorly as a targeted countermeasure. On the other hand, a desperate state – perhaps one that is also claiming a necessity defense – might argue that all countries have failed to abate their GHG emissions sufficiently and are therefore subject to countermeasures.

Compensation for harm from hazardous activities that were *not* contrary to international law is the subject of the ILC's second document regarding ex post obligations of states. Notably, given the lack of consensus on this matter, these provisions were released as Draft Principles instead of Draft Articles, and do not necessarily reflect customary international law. Nevertheless, the document can help to guide leading scholars' thinking and customary law's possible future direction. The Draft Principles address only transboundary damage, including "impairment of the environment" and any "reasonable response measures," that resulted from hazardous activities, defined as those "which [involve] a risk of causing significant harm."[392] The country in whose jurisdiction or under whose control the hazardous activity was carried out is considered the state of origin.

In the event of an activity involving a hazardous activity that is likely to cause transboundary damage, the state of origin must notify, consult with, and seek the cooperation of potentially affected states, as well as take appropriate response measures.[393] At the same time, the potentially affected state must "take all feasible measures" to minimize the damage. If a hazardous activity did cause transboundary damage, then the state of origin "should take all necessary measures to ensure that prompt and adequate compensation is available for victims."[394] Furthermore, it should impose strict liability on the operator who carries out the hazardous activity, and must ensure that its domestic courts and other public institutions can provide "prompt, adequate and effective remedies" to the victims of transboundary harm, without discrimination regarding victims' country of residence.[395] In other words, the Draft Principles do not claim that the state of origin is liable for damages, only that it should take steps to ensure that victims of transboundary harm have access to compensation and other remedies. This arrangement could occur through a variety of mechanisms including explicit and preferably strict liability for harm on the part of the operator, nondiscriminatory access to courts and other legal avenues of redress, mandatory insurance, industry-wide and international compensation funds, as well as possibly vicarious state liability. Finally, states should make all efforts to establish compensation regimes for particular categories of hazardous activities.[396] These regimes should rely, as appropriate, on industry-wide and/or state funds to supplement the resources and insurance cover of the operator.

Some scholars have explored whether a category of ultrahazardous or abnormally dangerous activities exists that would render states or operators strictly liable under the customary international law for transboundary harm arising from them.[397] These terms are used only in the ILC's commentary to the Draft Principles (which do not necessarily reflect customary international law in any case). There, the ILC notes that strict liability for ultrahazardous activities is the "most proper technique."[398] Indeed, that is the tradition within many domestic jurisdictions, and an economic analysis generally supports it. However, within international law, strict liability for seemingly ultrahazardous activities has so far been limited to those three classes that are the subjects of dedicated multilateral agreements or regimes: nuclear energy, activities in space, and the maritime transport of oil.

3.6.4. *UN International Law Commission Draft Articles on the Protection of the Atmosphere*

In 2011 the ILC began work toward a set of guidelines that would offer an international legal framework for the protection of the atmosphere, and in 2016 it provisionally approved such a draft set. One of these guidelines states, "Activities aimed at intentional large-scale modification of the atmosphere should be conducted with prudence and caution, subject to any applicable rules of international law."[399] The accompanying commentary notes that this includes but is not limited to "what is commonly understood as 'geo-engineering,'" and that it aims neither to authorize nor prohibit such activities.[400] The phrase "activities aimed at intentional large-scale modification of the atmosphere" is based on ENMOD, and "prudence and caution" on rulings of the International Tribunal for the Law of the Sea. The commentary further says that "[t]he draft guideline is cast in hortatory language, aimed at encouraging the development of rules to govern such activities, within the regimes competent in the various fields relevant to atmospheric pollution and atmospheric degradation."[401] Beyond this, the draft guidelines largely consist of restatements of existing principles and customary international law, including the obligations to exercise due diligence, to conduct environmental impact assessments, and to utilize the atmosphere equitably. However, the draft guidelines apply these to the atmosphere, with no explicit reference to transboundary risks in the guidelines themselves.

The drafting process is not complete, and further changes are likely.

3.7. PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW

General principles are the third main source of international law. They are not themselves legally binding, but instead must be operationalized in custom or a treaty. Their primary purpose is to provide guidance for the interpretation and further development of international law. That is, they can be thought of as the spirit, as opposed to the letter, of the law. Even more so than customary international law, the identity and substance of principles is not fully agreed-upon. This section introduces some of the leading principles of international environmental law, and what they could mean for the international law of climate engineering.

3.7.1. *The Environment as a Common Concern of Humankind*

Some multilateral agreements explicitly designate certain aspects of the environment – including the conservation of biological diversity in the

CBD and climate change in the UNFCCC – as the common concerns of humankind.[402] Furthermore, international environmental law implicitly treats other components such as stratospheric ozone, Antarctica, and the marine environment, as well as the global environment in general, as common concerns. As a principle, this designation does not have clear legal consequences, but for the most part, it has resulted in all states having individual and collective legitimate interests in and responsibilities for the maintenance of the common concern, independent of any direct harm to other Parties. Legally speaking, these responsibilities are akin to *erga omnes* obligations, which countries owe to the international community as a whole.

Climate engineering, especially SRM, can be reasonably inferred to affect a common concern of humankind, given "that change in the Earth's climate and its adverse effects are a common concern of humankind" per the universally ratified UNFCCC. Thus, unilateral or minilateral implementation of global climate engineering in the absence of notification and consultation with other states, whether or not they would be likely to experience deleterious effects, as well as other customary obligations would be contrary to this principle of international environmental law. Furthermore, its probable impacts on humanity's common concern should guide the development of any international law specific to climate engineering.

3.7.2. *Common but Differentiated Responsibilities*

In contrast to most international legal obligations, states are not to share some environmental responsibilities equally. Instead, restoring stratospheric ozone, preventing climate change, the conservation of biological diversity, the preservation of the marine environment, and environmental protection in general are explicitly or implicitly treated in international environmental law as common but differentiated responsibilities.[403] This principle recognizes that, despite the equality of sovereign states under international law, their environmental responsibilities need not be uniform. All Parties have some responsibilities toward the goals and in the specific commitments at hand, but those countries with the greater capacity – i.e., the wealthier ones – must bear disproportionate obligations to satisfy them. For example, the principle of the UNFCCC regarding common but differentiated responsibilities concludes: "Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof."[404] Both the Kyoto Protocol and the Paris Agreement continue and affirm this approach.

The principle of common but differentiated responsibilities implies that wealthier countries should carry most of the burdens of researching, developing, and implementing (if appropriate) climate engineering. In the specific case of the UNFCCC and its related agreements, this implication extends most clearly to CDR, given that their substantive content largely works toward the stabilization of GHG concentrations. However, one of the Paris Agreement's goals is the limitation of planetary warming, which states might be able to achieve – at least in part – through SRM.[405] In addition, the UNFCCC also calls on Parties to cooperate in research concerning undefined "various response strategies," and the Parties note, in the Paris Agreement, "the importance of technology for the implementation of mitigation and adaptation actions" and commit to "cooperative action on technology development and transfer."[406] Both of these terms – various response strategies and technology development, including for adaptation actions – might include both CDR and SRM climate engineering.

3.7.3. *Precaution*

Precaution, expressed as a principle or an approach, has been an increasingly common feature of international environmental law in recent decades. It is a legal tool to manage risk and uncertainty that is frequently cited when confronting issues of emerging technologies. Its particular formulations in the Rio Declaration, the CBD, the UNFCCC, CLRTAP's Oslo Protocol, the London Protocol, and the Kiev Protocol to the Aarhus Convention vary slightly.[407] The formulation in the UNFCCC is both typical and most relevant for climate engineering:

> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors.[408]

Scholars have debated precaution's meaning for climate engineering, given that climate change does and climate engineering might pose "threats of serious or irreversible damage" while demonstrating some "lack of full scientific certainty." As with the other instances where the risks and benefits of these two climatic phenomena seem to be in tension, any interpretation of this principle will depend on the specific technique, circumstances, and evidence at hand. This author has elsewhere asserted that precaution, as embodied in the UNFCCC, calls at least for the consideration, such as through research, of all means to reduce climate change risks, including that of climate engineering.[409] This argument relies upon the UNFCCC's call for precautionary measures to mitigate climate change's adverse effects, for measures and policies to be cost-effective, and for comprehensive consideration in developing response measures. Furthermore, "precautionary measures" is neither defined nor restricted, and the term could include not only CDR, which is clearly within the UNFCCC's scope and commitments, but also SRM. This position appears to be consistent with the decisions of the Parties to the London Protocol regarding marine geoengineering, which also requires a precautionary approach. In that case, both the nonbinding assessment framework for ocean fertilization and the approved amendment to regulate all marine geoengineering permit legitimate scientific research.[410]

3.7.4. *Polluter Pays*

A fourth principle of international environmental law is that the polluter, not the victim, should pay for environmental damage. However, despite the normative appeal of requiring the party who caused the harm to bear the burden of reparations, its implementation in international environmental law has been inconsistent, has been mainly in regional treaties, and often has utilized highly qualified language.[411] The principle was written into both the Rio Declaration and the London Protocol.[412] It is noticeably absent in the UNFCCC, despite this convention being drafted at the same time as the Rio Declaration.

To the extent that a principle of such limited acceptance were to apply to climate engineering, it could have two modalities of application. The primary cause of climate change is GHGs – a type of pollution – and climate engineering may offer a means to reduce their occurrence and/or effect. If so, then those states that have contributed most to the elevated atmospheric GHG concentrations should bear the costs of the means to reduce the risks from climate change, including any climate engineering research and implementation. The secondary source of "pollution" could be climate engineering itself, which might cause deleterious effects. It is less clear who should pay for any resulting damage, such as through environmental restoration and compensation for victims of harm, under the polluter pays principle. The states or other actors that implemented or undertook large-scale research or implementation of climate engineering are the most proximal source, yet the GHG-emitting states are the ultimate source of most

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climate change. This matter is clearly related to that of liability for harm from climate engineering.[413]

3.7.5. *Cooperation*

The obligation for states to cooperate in good faith is one of the cornerstones of international law. It was embodied in the Charter of the UN, and has since been explicitly stated or relied upon in most multilateral environmental agreements and in customary international law.[414] Note that cooperation does not demand agreement among states, only that they act in good faith and with due diligence regarding actions that might affect other countries. Because of its widespread application, the principle of cooperation is already legally binding in most climate engineering contexts through the UNFCCC or the customary law of preventing transboundary harm. Any future new legal instruments that would be specific to climate engineering should, at the very least, call upon states to cooperate in research and to share the results thereof. Moreover, they should require states, especially those engaged in climate engineering that would pose risks to other states, to notify, to share information, and to consult with one another.

3.7.6. *Equity*

A final principle of international environmental law is that of equity: acting with due regard for others' interests. Equity can include less direct effects than those captured by other legal concepts such as transboundary harm, and is particularly relevant when the potentially affected party is somehow disenfranchised or unable to effectively consult and negotiate with the decision-maker. Equity can be divided into that within and that between generations.

In the context of international environmental law, intragenerational equity can be thought of as a general normative framework that can guide the division of rights and obligations among states, underlying the related principles of cooperation and common but differentiated responsibilities. It considers the substantially uneven distribution of the impacts of states' actions. For example, ocean fertilization CDR could enable the acting state to meet its commitments to abate its net GHG emissions, yet might reduce marine resources on which other states depend for food and income. Likewise, the implementation of stratospheric aerosol injection SRM could reduce climate risks for many states, yet might change precipitation in some of them, putting their agricultural systems at risk. In this way, intragenerational equity resembles the prevention of transboundary harm, although the former can take a global perspective while the latter focuses primarily on bilateral relations. Equity is especially important in the management of shared resources as seen, for example, in the first principle of the UNFCCC:

> The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities.[415]

The second form of equity – intergenerational equity – concerns future populations who inherently lack self-representation in present discussions. Given the long length of time required before elevated atmospheric carbon dioxide concentrations will naturally lower, as well as the potentially high opportunity costs of foregone investments due to emissions abatement and adaptation, intergenerational equity is critical in the formulation of climate policy, yet it remains ambiguous and elusive.

For climate engineering, effects of both climate change and climate engineering on populations who lack an effective voice in governance will require particular attention. The principle of intergenerational equity implies that implementation of any climate engineering with global effects, such as SRM, should be subject to careful consideration and a high degree of scrutiny, especially in the absence of widespread consensus in the international community. The implications of intergenerational equity are complicated by the fact that, under conditions of elevated atmospheric GHG concentrations, SRM would need to be maintained for durations that would cross generations. On the one hand, transferring a burden to maintain such systems may be contrary to the principle of intergenerational equity.[416] At the same time, all other things being equal and assuming that climate engineering methods would function as planned, it appears contrary to intergenerational equity to fail to research, develop, and potentially implement a potential additional means to reduce climate risks – which will be borne almost entirely by future generations. For now, the cautious exploration of various climate engineering options through research appears to be consistent with the principle of intergenerational equity.

3.8. THE SCHOLARSHIP OF INTERNATIONAL ENVIRONMENTAL LAW AND CLIMATE ENGINEERING: THE PAST, CHALLENGES, AND THE FUTURE

The legal scholarship concerning climate engineering, particularly its international aspects, is now large and diverse enough that it can genuinely be called a body of scholarship. Although the first article to be published on this subject is more than 20 years old, the majority of these publications, which number well over 100, have appeared since 2013.[417] Some of the early essays offered introductory overviews to climate engineering proposals and the legal challenges that they posed.[418] Many of the writings – like this chapter – explored how existing international law could apply to climate engineering's various proposals.[419] Others offered suggestions for how climate engineering should be internationally governed.[420] These groups are not mutually exclusive.

More recent research has become more focused, and in some ways, more sophisticated. Often, it disaggregates the legal issues based upon the various climate engineering methods,[421] by where they would take place,[422] or by distinguishing research from implementation.[423] Ocean fertilization was a notable forerunner to these trends due to the controversial proposals in 2007 and the responses by the institutions of the CBD and of the London Convention and London Protocol.[424] Some scholars have looked to existing analogous technologies from which they could draw lessons,[425] including exploring to what extent the emerging international regulation of ocean fertilization could serve as a model for climate engineering more generally.[426] Instead of specific or detailed proposals for regulation, some articles offer modest suggestions for governance, such as principles or key issues, which may be more useful at this early stage.[427]

The most fruitful outputs from the last few years have been those that delve more deeply into particular legal aspects of and challenges posed by climate engineering. These include liability for harm,[428] intellectual property,[429] dispute settlement,[430] problematic uni- or minilateral implementation,[431] the concern of lessened GHG emissions abatement,[432] and its relationship with particular tenets of customary international law and general principles of international environmental law.[433] Finally, some recent scholarship uses climate engineering as a lens through which the authors can examine legal phenomena.[434]

Nevertheless, climate engineering continues to present challenges for the scholarship of international law, and especially that of environmental law. The first source of this difficulty is that climate engineering, due to its plural potential modalities, locations, and effects, invokes numerous international legal instruments. These were crafted at various times, by various parties, for various reasons, and are consequently often in tension with one another. Legal scholars must confront these tensions.

A second source of difficulty is the many ways in which climate engineering could both decrease and increase environmental risks – a phenomenon that this chapter has emphasized. Yet environmental law is generally oriented toward decreasing risks, and is poorly equipped to balance difficult and uncertain risk–risk tradeoffs.[435]

Third, SRM climate engineering presents a distinct problem structure, in that it would be a single best effort global public good.[436] The present evidence is that, in a world of inadequate efforts to reduce GHG emissions, SRM could be a global public good with large net benefits, although some groups and regions would lose in relative terms, and possibly in absolute terms.[437] These single best effort global public goods call for coordination, mutual restraint, and prevention of misuse. In contrast, environmental law generally strives to prevent and reduce negative externalities, such as pollution, and to manage common pool resources, such as the oceans and the atmosphere. These problems – which SRM also presents – are best controlled through mechanisms such as rules, legally binding commitments, liability, Pigouvian taxes, information disclosure, mandatory consultation and negotiation, and impact assessment.

Fourth, modern environmental law arose out of the justified recognition that humans were not properly accounting for all of the effects of our actions on the environment and on humans with the environment as the medium of harm. This lack of full accounting of impacts seemed most evident in cases of large-scale technological endeavors. Most responses to this, both within and beyond legal scholarship, have focused on reducing interventions in the environment, and on humility in our collective endeavors. Climate engineering runs counter to this cultural milieu. Indeed, the proposals are more congruent with the increasing recognition that humanity now influences the natural world to such a degree that a new geologic era – the Anthropocene – may be warranted.[438] The result of the latter two challenges to environmental legal scholarship listed here – those of problem structure and historical culture – is that many writers approach climate engineering proposals solely as risky, if not hubristic, interventions in the natural world that will have negative impacts on species, ecosystems, and humans, and which will damage our shared resources. This approach offers a picture that is far from complete.

Looking forward, scholars of international law should reflect upon these challenges. Those who work in the environmental vein should strive to understand and integrate diverse problem structures into their analyses, and use climate engineering as an opportunity to examine and make explicit their objectives, which are often left unstated. Furthermore, the examination of the international law of climate engineering has, understandably, been dominated by experts of environmental law. Yet a broader range of specialties is now needed. Chief among these are those of intellectual property, given the importance of patents as a means to regulate technologies, and of human rights, considering the potential yet unclear capacity for climate engineering to impact their provision. Within international environmental law, more attention is warranted on how its principles could and should guide the interpretation of existing law and the development of any future law of climate engineering. Besides precaution, other general international legal principles remain largely unexplored. Finally, research on the law of climate engineering could benefit through integration with the growing legal scholarship of the Anthropocene.

NOTES

1 *See* Durwood Zaelke and James Cameron, *Global Warming and Climate Change: An Overview of the International Legal Process*, 5 AMERICAN UNIVERSITY JOURNAL OF INTERNATIONAL LAW AND POLICY 249 (1989).

2 Cirrus cloud thinning, in which more heat is allowed to escape the Earth, seems to offer a third category of climate engineering. Because it resembles SRM in terms of its problem structure and atmospheric means of operation, the term "SRM" in this chapter generally includes cirrus cloud thinning. At the same time, cirrus cloud thinning is like CDR in that it influences the Earth's balance of long-wave radiation.

3 Daniel Bodansky, *May We Engineer the Climate?*, 33 CLIMATIC CHANGE 309 (1996). For a review and some history, particularly of the relevant international relations aspects, see Joshua B. Horton and Jesse L. Reynolds, *The International Politics of Climate Engineering: A Review and Prospectus for International Relations*, 18 INTERNATIONAL STUDIES REVIEW 438 (2016).

4 "Nonexcludable" means that the producer cannot effectively exclude others from enjoying the benefits of the good. "Nonrivalrous" means that enjoyment of the good by one party does not diminish the ability of others to enjoy it. Note that a "good" is meant here in the descriptive sense of a product or service, not in any normative sense. A public good is often desired by some and not by others, and is thus normatively neither good nor bad. Also note that a public good is an ideal type. In reality, goods have characteristics that place them along a spectrum. *See* Scott Barrett, *Why Cooperate? The Incentive to Supply Global Public Goods* (Oxford: Oxford University Press, 2007); Daniel Bodansky, *What's in a Concept? Global Public Goods, International Law, and Legitimacy*, 23 EUROPEAN JOURNAL OF INTERNATIONAL LAW 651 (2012). Adapting society to a changed climate is not a global public good.

5 Note that CDR (as well as many forms of abatement) would also have negative externalities, in some cases possibly negating at least some of its global benefits. Hypothetical ultra-cheap CDR could resemble SRM, allowing single actors at the country-level scale to experience net direct benefits, even in the absence of global cooperation. This presently appears to be an unlikely scenario. Many forms of GHG abatement also have positive externalities that provide direct and immediate local benefits, in particular a reduction in levels of conventional air pollutants.

6 Likewise, the negative impacts of SRM might be great enough to outweigh its benefits.

7 William Nordhaus, *A Question of Balance: Weighing the Options on Global Warming Policies* (New Haven: Yale University Press, 2008), 196.

8 Some legal scholars reject trying to balance the expected effects of climate engineering and climate change. *See, e.g.*, Ralph Bodle et al., *Options and Proposals for the International Governance of Geoengineering*, 14/2014 CLIMATE CHANGE, UMWELTBUNDESAMT/FEDERAL ENVIRONMENT AGENCY (GERMANY) 98, 136 (2014); Wilfried Rickels et al., *Large-Scale Intentional Interventions into the Climate System? Assessing the Climate Engineering Debate* (Kiel: Kiel Earth Institute, 2011).

9 States sometimes consent to external authorities, such as the European Union and the UN Security Council, having such authority. States may withdraw such consent, albeit with consequences that might be negative.

10 This right is coupled with a state's responsibility to ensure that its activities do not cause harm to another state or to areas beyond national jurisdiction. *See* The Rio Declaration on Environment and Development (1992), Principle 2. *See* section 3.6.2.

11 There are jurisdictional claims in Antarctica, but these are not widely recognized.

12 Vienna Convention on the Law of Treaties (1969) [hereinafter Vienna Treaties Convention], Art. 1.

13 *Id.*, Art. 56.

14 Andrew T. Guzman, *How International Law Works: A Rational Choice Theory* (Oxford: Oxford University Press, 2008).

15 Vienna Treaties Convention, Art. 60.

16 Eric A. Posner and Alan O. Sykes, *Economic Foundations of International Law* (Cambridge, MA: Harvard University Press, 2013), 32.

17 Patricia W. Birnie, Alan E. Boyle, and Catherine Redgwell, *International Law and the Environment* (Oxford: Oxford University Press, 2009), 7.

18 *The Changing Atmosphere: Implications for Global Security*, statement of the World Conference on the Changing Atmosphere, Toronto, Canada, June 27–30, 1988, para. 30; *Protection of the Atmosphere: International Meeting of Legal and Policy Experts: Statement of the Meeting of Legal Policy Experts*, Ottawa, Canada, February 20–22, 1989. Both are reprinted in Center for International and Environmental Law, *Selected International Legal Materials on Global Warming and Climate Change*, 5 AMERICAN UNIVERSITY JOURNAL OF INTERNATIONAL LAW AND POLICY 513 (1990). *See also* James K. Sebenius, *Designing Negotiations Toward a New Regime: The Case of Global Warming*, 15 INTERNATIONAL SECURITY 110, 115–16 (1991).

19 *See* section 3.4.4.

20 Report of the International Law Commission, Sixty-eighth Session (A/71/10) (2016), Ch. VIII.

21 The Holy See and Palestine are not Parties but only observer states.

22 United Nations Framework Convention on Climate Change (1992) [hereinafter UNFCCC], Art. 2.

23 Paris Agreement (2015), Art. 2.1(a). The carbon dioxide limit assumes a climate sensitivity of 3°C.

24 "Business as usual" here means the RCP8.5 scenario. Detlef P. van Vuuren et al., *The Representative Concentration Pathways: An Overview*, 109 CLIMATIC CHANGE 5 (2011).

25 *See* Sabine Fuss et al., *Betting on Negative Emissions*, 4 NATURE CLIMATE CHANGE 850 (2014); T. Gasser et al., *Negative Emissions Physically Needed to Keep Global Warming Below 2°C*, 6 NATURE COMMUNICATIONS 7958 (2015).

26 As described above, both emissions abatement and SRM are global public goods. However, the benefits of the former to a single country generally do not outweigh the costs, whereas they might in the case of the latter. *See* Jesse Reynolds, *A Critical Examination of the Climate Engineering Moral Hazard and Risk Compensation Concern*, 2 THE ANTHROPOCENE REVIEW 174, 175–83 (2015).

27 UNFCCC, Preamble para. 1, Arts. 3.1, 3.3, 4.

28 *Id.*, Preamble para. 8.

29 *Id.*, Art. 3.1.

30 *Id.*, Arts. 4.1(f), 3.3. *See also* Preamble paras. 10, 16, 21, 22, Arts. 3.4, 3.5, 4.1(g), 4.1(h), 4.2(a), 4.7, 4.10, 7.2(a).

31 *Id.*, Art. 4.1(f).

32 *Id.*

33 *Id.*, Arts. 4.1(b), 4.1(d), 4.2(a).

34 *Id.*, Art. 4.1(d).

35 *Id.*, Arts. 1.7, 1.8. Indeed, any line that tries to separate CDR methods from traditional abatement activities would be unclear.

36 *Id.*, Art. 4.1(g). *See also* Arts. 4.1(h), 5.

37 *Id.*, Art. 4.1(c). *See also* Arts. 4.3, 4.5, 4.7, 4.8, 4.9.

38 Report of the Conference of the Parties on its Sixteenth Session, Held in Cancún from 29 November to 10 December 2010, Addendum Part Two: Action Taken by the Conference of the Parties at its Sixteenth Session (2011), paras. 113–127.

39 UNFCCC, Arts. 3.3, 4.1(b), 4.1(e), 4.1(f), 4.4.

40 *See* UNFCCC, *Focus: Adaptation*, http://unfccc.int/focus/adaptation/items/6999.php.

41 Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997) [hereinafter Kyoto Protocol], Arts. 2.1(a)(iv), 10(c), 10(d). *See also* Arts. 10(b)(i), 11.2(b).

42 *Id.*, Arts. 2.1(a)(ii), 2.1(a)(iv).

43 *Id.*, Art. 3.3. Developing means to account for the removal of GHGs through land use change and forestry activities has been a long, contentious, and still unresolved process.

44 *Id.*, Art. 3.4.

45 Report of the Conference of the Parties Serving as the Meeting of the Parties to the Kyoto Protocol on Its Eighth Session, Addendum Part Two (2012), Decision 1/CMP.8.

46 *Id.*, Arts. 5, 7.1, 10, especially 10(b)(ii).

47 *Id.*, Arts. 6, 12.

48 Paris Agreement (2015), Art. 1.2(a).

49 United Nations Environment Programme, *The Emissions Gap Report 2016* (Nairobi: United Nations Environment Programme, 2016).
50 Paris Agreement, Art. 4.1.
51 *Id.*, Art. 4.2.
52 *Id.*, Art. 6.
53 Phillip Williamson et al., *Ocean Fertilization for Geoengineering: A Review of Effectiveness, Environmental Impacts and Emerging Governance*, 90 PROCESS SAFETY AND ENVIRONMENTAL PROTECTION 475 (2012).
54 *Id.*, Arts. 1.2(b), 7.
55 *Id.*
56 *Id.*, Arts. 7.9, 7.11, 7.14.
57 *Id.*, Art. 7.5.
58 UNFCCC, Arts. 7, 8, 9, 14. *See* Meinhard Doelle, *Geo-engineering and Dispute Settlement under UNCLOS and the UNFCCC: Stormy Seas Ahead?*, in CLIMATE CHANGE IMPACTS ON OCEAN AND COASTAL LAW: U.S. AND INTERNATIONAL PERSPECTIVES (Randall S. Abate, ed., Oxford: Oxford University Press, 2014).
59 Compare Matthias Honegger, Kushini Sugathapala, and Axel Michaelowa, *Tackling Climate Change: Where Can the Generic Framework Be Located?*, 7 CARBON AND CLIMATE LAW REVIEW 125 (2013); Jesse Reynolds, *Why the UNFCCC and CBD Should Refrain from Regulating Solar Climate Engineering*, in GEOENGINEERING OUR CLIMATE? ETHICS, POLITICS AND GOVERNANCE (Jason Blackstock and Sean Lo, eds., Abingdon: Routledge, 2018).
60 *See* A. F. Bais et al., *Ozone Depletion and Climate Change: Impacts on UV Radiation*, 14 PHOTOCHEMICAL & PHOTOBIOLOGICAL SCIENCES 19 (2015).
61 Giovanni Pitari et al., *Stratospheric Ozone Response to Sulfate Geoengineering: Results from the Geoengineering Model Intercomparison Project (GeoMIP)*, 119 JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES 2629 (2014).
62 John A. Dykema et al., *Stratospheric Controlled Perturbation Experiment: A Small-scale Experiment to Improve Understanding of the Risks of Solar Geoengineering*, 372 PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A: MATHEMATICAL, PHYSICAL AND ENGINEERING SCIENCES 0059 (2014); David W. Keith et al., *Stratospheric Solar Geoengineering without Ozone Loss*, 113 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES 14910–14 (2016).
63 S. Roumeau et al., *Tropical Cirrus Clouds: A Possible Sink for Ozone*, 27 GEOPHYSICAL RESEARCH LETTERS 2233 (2000); Eric J. Jensen et al., *Ice Nucleation and Dehydration in the Tropical Tropopause Layer*, 110 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES 2041 (2013).
64 Vienna Convention for the Protection of the Ozone Layer (1985) [hereinafer Vienna Ozone Convention], Art. 2.2(b).
65 Montreal Protocol on Substances That Deplete the Ozone Layer (1987) [hereinafter Montreal Protocol], Art. 2.10.
66 Vienna Ozone Convention, Art. 2.1.
67 Annual global lower atmospheric sulfur pollution is roughly 100 megatons of sulfur dioxide (50 megatons of sulfur) and declining. Offsetting the warming effect of the doubling of the atmospheric carbon dioxide concentration would require roughly 3 to 10 megatons of sulfur dioxide (1.5 to 5 megatons of sulfur). *See* Z. Klimont et al., *The Last Decade of Global Anthropogenic Sulfur Dioxide: 2000–2011 Emissions*,

8 ENVIRONMENTAL RESEARCH LETTERS 014003 (2013); Naomi E. Vaughan and Timothy M. Lenton, *A Review of Climate Geoengineering Proposals*, 109 CLIMATIC CHANGE 791, 810 (2011). Sulfate aerosols in the lower atmosphere presently offset approximately a quarter of climate change but are much less effective due to their shorter residence time and suboptimal particle size. *See* Olivier Boucher et al., *Clouds and Aerosols*, in CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS (Thomas F. Stocker et al., eds., Cambridge: Cambridge University Press, 2013); Ben Kravitz, *Stratospheric Aerosols for Solar Radiation Management*, in GEOENGINEERING RESPONSES TO CLIMATE CHANGE: SELECTED ENTRIES FROM THE ENCYCLOPEDIA OF SUSTAINABILITY SCIENCE AND TECHNOLOGY (Tim Lenton and Naomi Vaughan, eds., New York: Springer, 2013), 24.

68 Vienna Ozone Convention, Arts. 2.2(a), 3.1.

69 Montreal Protocol, Arts. 9, 10A.

70 Convention on Long-Range Transboundary Air Pollution (1979) [hereinafter CLRTAP], Arts. 3–6, 8.

71 *Id.*, Art. 2.

72 *Id.*, Art. 1(a). *See* Philippe Sands and Jacqueline Peel, *Principles of International Environmental Law* (Cambridge: Cambridge University Press, 2012), 247.

73 CLRTAP, Arts. 5, 8. Note the lower threshold for consultation, in which source states must consult, upon request by states that are merely at risk or affected by long-range transboundary air pollution. *See also* Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at Least 30 per Cent (1985), Art. 4; Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions (1994) [hereinafter Oslo Protocol], Art. 5; Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-level Ozone (1999) [hereinafter Gothenburg Protocol], Art. 7.

74 CLRTAP, Art. 7.

75 *Id.*, Art. 6.

76 Note that several larger states, including Canada, Russia, the United Kingdom, and the USA, that have ratified CLRTAP are not Parties to one or more of these three Protocols.

77 Oslo Protocol, Art. 6.

78 CLRTAP, Arts. 2–3; Oslo Protocol, Art. 2.1; Gothenburg Protocol, Art. 2.1.

79 The other areas beyond national jurisdiction are outer space and (arguably) Antarctica.

80 The primary objections of the USA were to the agreement's provisions regarding the sharing of the resources of the seabed. A minority in the Senate presently blocks its ratification.

81 United Nations Convention on the Law of the Sea (1982) [hereinafter UNCLOS], Art. 192.

82 Mark J. Valencia and Kazumine Akimoto, *Guidelines for Navigation and Overflight in the Exclusive Economic Zone*, 30 MARINE POLICY 704, 708 (2006); Veronica Frank, *The European Community and Marine Environmental Protection in the International Law of the Sea: Implementing Global Obligations at the Regional Level* (Leiden: Martinus Nijhoff, 2007), 12.

83 UNCLOS, Art. 193.
84 *Id.*, Art. 197.
85 *Id.*, Art. 1.1(4).
86 *See* Alan Boyle, *Law of the Sea Perspectives on Climate Change*, 27 THE INTERNATIONAL JOURNAL OF MARINE AND COASTAL LAW 831, 832–33 (2012).
87 UNCLOS, Arts. 194, 196, 198–199, 204–22. Note that a coastal state may regulate foreign vessels in its exclusive economic zone (EEZ) outside of its territorial waters in order to minimize pollution only to operationalize generally accepted international standards, whereas inside its territorial waters it may do so to higher standards, provided that this does not interfere with innocent passage. *See id.*, Art. 211.4–5.
88 *Id.*, Arts. 61, 117–120, 194.5.
89 *Id.*, Arts. 194, 212.2.
90 *Id.*, Arts. 194, 196.
91 *Id.*, Arts. 204–206.
92 *Id.*, Art. 195.
93 James Edward Peterson, *Can Algae Save Civilization?: A Look at Technology, Law, and Policy Regarding Iron Fertilization of the Ocean to Counteract the Greenhouse Effect*, 6 COLORADO JOURNAL OF INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 61, 92 (1995).
94 Philomene Verlaan, *Geo-engineering, the Law of the Sea, and Climate Change*, 3 CARBON AND CLIMATE LAW REVIEW 446, 458 (2009).
95 Monika Rhein et al., *Observations: Ocean*, in CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS (Thomas F. Stocker et al., eds., Cambridge: Cambridge University Press, 2013), 292.
96 For example, proposals discussed during negotiations included "any study or related experimental work designed to increase man's knowledge of the marine environment." Informal Single Negotiating Text, Part III, Third United Nations Conference on the Law of the Sea, Volume IV, Summary Records, Plenary, General Committee, First, Second and Third Committees, as well as Documents of the Conference, Third Session (1975), Art. 1. *See* UN Division for Ocean Affairs and the Law of the Sea, Office of Legal Affairs, *The Law of the Sea: Marine Scientific Research: A Revised Guide to the Implementation of the Relevant Provisions of the United Nations Convention on the Law of the Sea* (New York: United Nations, 2010); Philomene Verlaan, *Marine Scientific Research: Its Potential Contribution to Achieving Responsible High Seas Governance*, 27 THE INTERNATIONAL JOURNAL OF MARINE AND COASTAL LAW 805 (2012). In contrast, the International Law Association (American Branch) Law of the Sea Committee requires that it be "undertaken in ocean space." George K. Walker, ed., *Definitions for the Law of the Sea: Terms Not Defined by the 1982 Convention* (Leiden: Martinus Nijhoff, 2011), 241.
97 UNCLOS, Arts. 238–239, 242–244.
98 *Id.*, Art.204.1.
99 *Id.*, Art. 238.
100 *Id.*, Art. 240. *See* Philomene A. Verlaan, *Experimental Activities that Intentionally Perturb the Marine Environment: Implications for the Marine Environmental Protection and Marine Scientific Research Provisions of the 1982 United Nations Convention on the Law of the Sea*, 31 MARINE POLICY 210 (2007); Anna-Maria

Hubert, *The New Paradox in Marine Scientific Research: Regulating the Potential Environmental Impacts of Conducting Ocean Science*, 42 Ocean Development and International Law 329 (2011).

101 UNCLOS, Art. 263.

102 *Id.*, Arts. 91–92. Flag states do not consistently comply with the requirements regarding the oversight of ships that bear their flag, including the one that there be a genuine link. *See* Alan Khee-Jin Tan, *Vessel-Source Marine Pollution: The Law and Politics of International Regulation* (Cambridge: Cambridge University Press, 2005), 47–62.

103 *Id.*, Arts. 94, 211.2.

104 *Id.*, Arts. 2–3.

105 *Id.*, Art. 17.

106 *Id.*, Arts. 18–19. Other causes for a ship engaged in climate engineering to not be in innocent passage include that the passage itself might not be "continuous and expeditious," the activity could be an "act of willful and serious pollution contrary to" UNCLOS, or the ship could be "carrying out … research or survey activities."

107 *Id.*, Art. 245.

108 *Id.*, Arts. 27, 220, 230.2. *See* International Law Association Committee on Coastal State Jurisdiction Relating to Marine Pollution, *Final Report: London Conference (2000)*, *in* *Vessel-Source Pollution and Coastal State Jurisdiction: The Work of the ILA Committee on Coastal State Jurisdiction Relating to Marine Pollution (1991–2000)*, (Erik Franckx, ed., The Hague: Kluwer, 2001), Conclusions 7, 9.

109 UNCLOS, Arts. 117, 194, 196.

110 *Id.*, Arts. 55, 57. The 24 nautical miles from land is the contiguous zone of the coastal state, which is not relevant for our purposes here. *See id.*, Art. 33.

111 *Id.*, Art. 56.1.

112 *Id.*, Arts. 56.2, 58.3.

113 *Id.*, Art. 58.3.

114 Its right of the physical inspection and potential detention of the foreign ship are dependent upon the severity of the suspected pollution, and penalties are limited to monetary ones. *See id.*, Arts. 220, 230.

115 *Id.*, Art. 246. *See also* Arts. 252–253.

116 *Id.*, Arts. 248–249.

117 *Id.*, Art. 59.

118 *Id.*, Arts. 86–88, 257. Archipelagic Parties have sovereignty over archipelagic waters, which are excluded from the high seas. *See id.*, Arts. 46–49.

119 *Id.*, Art. 87.1.

120 *Id.*, Art. 94.7

121 *Id.*, Arts. 58.1, 87.1(b). *See* section 3.4.1 below. This provision, coupled with Art. 56.1, seems to grant coastal states jurisdiction over atmospheric SRM in their EEZs. For example, a group of "senior officials and analysts" developed a set of "Guidelines for Navigation and Overflight in the Exclusive Economic Zone." They concluded that "States exercising the freedoms of navigation and overflight in a coastal State's EEZ should not interfere with or endanger the rights of the coastal State to protect and manage its own resources and their environment." Valencia and Akimoto, *supra* note 82, at 709.

122 *See* Neil Craik, Jason J. Blackstock, and Anna-Maria Hubert, *Regulating Geoengineering Research through Domestic Environmental Protection Frameworks: Reflections on the Recent Canadian Ocean Fertilization Case*, 7 Carbon and Climate Law Review 117 (2013).
123 *Compare* UNCLOS, Arts. 194.2, 196, 206 *with* Arts. 139, 153, 235, 263.
124 *Id.*, Arts. 192, 194.1.
125 *Id.*, Art. 235.
126 *Id.*
127 Id., Art. 263.
128 *Id.*, Art. 232.
129 For the latter, *see id.*, Arts. 213, 222, in which Parties are to take "measures necessary to implement applicable international rules and standards established through competent international organizations or diplomatic conference to prevent, reduce and control pollution of the marine environment from land-based sources [and] … from or through the atmosphere."
130 *Id.*, Art. 139.
131 UNCLOS uses "living resources" and "marine life" distinctly, although both are undefined. Provisions regarding the former consistently refer to conservation, management, utilization, exploitation, and allowable catch, implying that they are organisms that are extracted for economic gain. The sole article that invokes only the latter is "to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life," implying a broader category. *Id.*, Arts. 61–68, 116–120, 194.5.
132 International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (1996).
133 UNCLOS, Art. 266.1.
134 *Id.*, Art. 266.2.
135 *Id.*, Art. 267.
136 It may be possible to store captured carbon dioxide on the seabed, because at the low temperature and high pressure there, carbon dioxide is denser than water and could consequently remain as lake-like pools of liquid and/or solid hydrates in the valleys and crevices of the seabed.
137 UNCLOS, Arts. 76–85, 133–191.
138 *Id.*, Arts. 76–81.
139 *Id.*, Art. 82. For a legal analysis of sub-seabed storage of carbon dioxide off the US Atlantic coast, *see* Romany M. Webb & Michael B. Gerrard, *Policy Readiness for Offshore Carbon Dioxide Storage in the Northeast* (Sabin Center for Climate Change Law, June 2017), available at http://columbiaclimatelaw.com/files/2017/06/Webb-and-Gerrard-2017-06-Offshore-Carbon-Storage.pdf.
140 UNCLOS, Art. 1.1(1).
141 *Id.*, Arts. 136, 138, 141, 156–185.
142 *Id.*, Art. 145. It has done so for prospecting and exploration for certain materials, including polymetallic nodules, polymetallic sulfides, and cobalt-rich ferromanganese crusts.
143 *Id.*, Art. 139.1.
144 *Id.*, Art. 143.

145 Convention for the Protection of the Marine Environment of the North-East Atlantic (1992); Amendments to Annex II and Annex III to the OSPAR Convention for the Protection of the Marine Environment in the North-East Atlantic in Relation to the Storage of Carbon Dioxide Streams in Geological Formations (2007).
146 Note that disposal need not be into the sea itself. *See* UNCLOS, Art. 1.1(5).
147 *Id.*, Preamble para. 4.
148 Scholarly opinion diverges on this point regarding ocean fertilization. Proelss and Güssow roughly agree (as set forth in Rickels et al.). Freestone and Rayfuse argue that ocean fertilization is dumping, because the carbon dioxide that is indirectly put into the water column is merely being disposed of. Scott asserts that it is dumping because it is very likely to cause pollution and is thus contrary to the aims of UNCLOS. *See* David Freestone and Rosemary Rayfuse, *Ocean Iron Fertilization and International Law*, 364 MARINE ECOLOGY PROGRESS SERIES 227, 229 (2008); Rickels et al., 94; Karen N. Scott, *Regulating Ocean Fertilization under International Law: The Risks*, 7 CARBON AND CLIMATE LAW REVIEW 108, 112 (2013).
149 UNCLOS, Art. 207.1.
150 *Id.*, Art. 194.3(a).
151 *Id.*, Art. 210.
152 *Id.*, Art. 210.4.
153 *Id.*, Art. 210.6.
154 Verlaan, INTERNATIONAL JOURNAL OF MARINE AND COASTAL LAW 810–11.
155 UNCLOS, Arts. 94.7, 211.2.
156 *See* Eric Van Hooydonk, *The Law of Unmanned Merchant Shipping: An Exploration*, 20 THE JOURNAL OF INTERNATIONAL MARITIME LAW 403 (2014).
157 UNCLOS, Art. 94.4.
158 *See* Chapter 2. *See also* Alexander Proelss and Chang Hong, *Ocean Upwelling and International Law*, 43 OCEAN DEVELOPMENT AND INTERNATIONAL LAW 371 (2012).
159 An ordinary reading of these terms implies that, within each of the contexts, they are listed in order of decreasing size.
160 UNCLOS, Art. 194.3(d). *See also* Art. 208.1 for an extension of this duty to artificial islands, installations, and structures that operate on the seabed.
161 *Id.*, Art. 262.
162 *Id.*, Arts. 56.1(b), 60, 80.
163 *Id.*, Art. 60.3. Scholars have concluded that due notice is "through appropriate authorities within a reasonable amount of time in a suitable manner … through diplomatic or other designated channels … [and perhaps] national hydrographic offices." Walker, *supra* note 96, at 176.
164 *Supra* note 8, at Art. 246.5(c).
165 *Id.*, Arts. 60.3–60.7, 249.1(g), 260–261.
166 *Id.*, Art. 87. UNCLOS has no provision requiring that non-research artificial islands, installations, and structures bear the identifying markings of the state of registry or the international organization to which they belongs. This implies that Parties may build or place them on the high seas without such markings, after which time they could persist without an identifying state. However, this could

interfere with other states exercising their own high seas freedoms. Furthermore, allowing such placement of unmarked objects would, if they created pollution of the marine environment, cause Parties to be noncompliant with their commitment to take all measures to ensure that "pollution from other installations and devices operating in the marine environment" is minimized. *See id.*, Art. 194.3(d).

167 R. R. Churchill and A. V. Lowe, *The Law of the Sea*, Third edn (Manchester: Manchester University Press, 1999), 24; Yoshifumi Tanaka, *The International Law of the Sea* (Cambridge: Cambridge University Press, 2012), 264.

168 UNCLOS, Annex VI. *See* Doelle, *supra* note 58.

169 UNCLOS, Art. 210.6. See Verlaan, supra note 96.

170 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 [hereinafter London Protocol] (1996), Art. 23. The USA is making "progress towards joining." Report of the Thirty-sixth Consultative Meeting of the London Convention and the Ninth Meeting of Contracting Parties of the London Protocol (2014), para. 2.7.

171 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter [hereinafter London Convention] (1972), Art. I; London Protocol, Art. 2.

172 London Protocol, Art. 1.10.

173 *Id.*, Art. 14.1.

174 *Id.*, Art. 3.3.

175 London Convention, Art. III.1; London Protocol, Art. 1.4.

176 London Convention, Art. IV.

177 *Id.*, Annex II, para. D.

178 London Protocol, Annex 1.

179 *Id.*, Art. 3.1.

180 *See* Bettina Boschen, *The Regulation of Ocean Fertilization and Marine Geoengineering under the London Protocol*, in CLIMATE CHANGE IMPACTS ON OCEAN AND COASTAL LAW: U.S. AND INTERNATIONAL PERSPECTIVES (Randall Abate, ed., Oxford: Oxford University Press, 2014); Harald Ginzky and Robyn Frost, *Marine Geo-engineering: Legally Binding Regulation under the London Protocol*, 8 CARBON AND CLIMATE LAW REVIEW 82 (2014).

181 Resolution LC-LP.1 on the Regulation of Ocean Fertilization (2008). This definition would also include fertilization via upwelling pipes. The resolution did not explicitly conclude that ocean fertilization was or was not dumping, only that ocean fertilization activities other than legitimate scientific research are contrary to the aims of the agreements and did not qualify for any exemption from the definition of dumping.

182 *Id.*, paras. 3–8.

183 Resolution LC-LP.2 on the Assessment Framework for Scientific Research Involving Ocean Fertilization (2010).

184 *Id.*, Sec. 2.

185 *Id.*, Sec. 3.

186 *Id.*, paras. 3.6.1, 4.3.

187 Resolution LP.4(8) on the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities (2013), Annex, Art. 1, adding new para. 5*bis*.

188 *Id.*, Annex, Art. 1, adding new Annex 4. The Parties are developing a guidance document for considering the inclusion of new activities in this Annex. *See* Report of the Thirty-sixth Consultative Meeting, *supra* note 170. In November 2015, a new working group of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, which advises the UN and its related bodies on the scientific aspects of pollution of the marine environment, was formed. It will explore the potential environmental impacts of marine geoengineering, in part to explore potential future forms of marine geoengineering to be listed in the amendment's annex.

189 London Protocol, Art. 22. The modifications then apply to each Party that does not declare "that they are not able to accept the amendment at that time." *Id.*

190 Res. LP.4(8), Annex, Art. 1, adding new Art. 6*bis*.

191 *Id.*, Annex, Art. 1, adding new Annex 4, para. 1.

192 *Id.*, Annex, Art. 1, adding new Art. 6*bis*.2.

193 *Id.*, Annex, Art. 1, adding new Annex 5. The existing ocean fertilization assessment framework is to serve as the specific assessment framework for that activity.

194 *Id.*, Annex, Art. 1, adding new Annex 5, para. 10.

195 *Id.*, Annex, Art. 1, adding new Annex 5, paras. 5, 8.

196 *Id.*, Annex, Art. 1, adding new Annex 5, para. 11.

197 *Id.*, Annex, Art. 1, adding new Annex 5, para. 12.

198 *Id.*, Annex, Art. 1, adding new Annex 5, para. 26.

199 *Id.*, Annex, Art. 1, adding new Annex 5, paras. 7–8.

200 With some creative interpretation, the definition could include even those activities that occur on or over land but impact in the marine environment. However, the regulatory scope of the amendment is limited to placement of matter into the sea, thus excluding atmospheric activities.

201 Res. LP.4(8), Preamble para. 1.

202 *Id.*, Annex, Art. 1, adding new Art. 6*bis*.3.

203 Verlaan, *supra* note 96; Ginzky and Frost, *supra* note 180, at 90.

204 Res. LP.4(8) Annex, Art. 1, adding new Annex 5, para. 26.5.

205 Report of the Twenty-first Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (2007), paras. 5.18–5.27. *See* Interpretation of the London Convention 1972: Mitigating the Environmental Impacts on the Oceans of Climate Change: Carbon Capture and Sequestration in the Marine Environment (submitted by the United Kingdom 2004).

206 2012 Specific Guidelines for the Assessment of Carbon Dioxide for Disposal into Sub-seabed Geological Formations (2012).

207 This amendment entered into force on February 10, 2007. The carbon dioxide stream must also be overwhelmingly pure. *See* London Protocol Annex 1, Art. 4.3.

208 Resolution LP.3(4) on the Amendment to Art. 6 of the London Protocol (Adopted on 30 October 2009), the Fourth Meeting of Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972. Such export would otherwise be prohibited by Article 6 of the Protocol.

209 *See* section 3.6.

210 Convention on Environmental Impact Assessment in a Transboundary Context (1991), Art. 1(v).
211 *Id.*, Art. 1(vii).
212 *Id.*, Art. 2.1.
213 *Id.*, Art. 9.
214 *Id.*, Art. 2.5.
215 *Id.*, App. II.
216 *Id.*, Arts. 2.2–2.3, 4, App. II.
217 *Id.*, Arts. 2.4, 3, 5.
218 *Id.*, Arts. 2.6, 3.8.
219 *Id.*, Art. 6.
220 *Id.*, Art. 2.7.
221 Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context (2003), Art. 4.1.
222 General categories include forestry, industry, waste management, and land use. Specific projects include large-diameter gas pipelines (presumably encompassing carbon dioxide, as elsewhere "natural gas" is stated), "[p]rojects for the use of uncultivated land or seminatural areas for intensive agricultural purposes," "[i]nitial afforestation and deforestation for the purposes of conversion to another type of land use," "[i]ndustrial installations for carrying gas," and deep drillings. *Id.*, Art. 4.2, Annexes I–II.
223 *Id.*, Art. 2.7.
224 *Id.*, Arts. 1(d), 2.6, 3.2, 5.3, 5.4, 6.3, 8, 11.2, 12.2.
225 *Id.*, Art. 9.
226 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters [hereinafter Aarhus Convention] (1998), Art. 1.
227 *Id.*, Art. 3.9.
228 *Id.*, Art. 2.3.
229 *Id.*, Art. 4.
230 *Id.*, Art. 5.
231 *Id.*, Art. 6, Annex I.
232 *Id.*, Arts. 7–8. *See* Svitlana Kravchenko, *The Aarhus Convention and Innovations in Compliance with Multilateral Environmental Agreements*, 18 Colorado Journal of International Environmental Law and Policy 1 (2007).
233 Aarhus Convention, Art. 9.
234 *Id.*, Art. 15. Members of the public and environmental organizations may bring complaints before a noncompliance committee, whose members are nominated by, among others, environmental organizations. The "non-confrontational, non-judicial and consultative" procedure results in recommendations for the noncompliant Party. The Meeting of Parties may suspend the treaty rights of a noncompliant Party.
235 Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters [hereinafter Kiev Protocol] (2003), Art. 1.
236 *Id.*, Art. 2.
237 *Id.*, Arts. 3–11.
238 *Id.*, Art. 3.4.

239 Convention on Biological Diversity [hereinafter CBD] (1992), Art. 1.

240 Reports issued by the CBD Secretariat have said as much, highlighting the tension between climate change and climate engineering: "If effective, geoengineering would reduce the impacts of climate change on biodiversity at the global level." Phillip Williamson and Ralph Bodle, *Update on Climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework* (Montreal: Secretariat of the CBD, 2016), 13.

241 CBD, Art. 3.

242 *Id.*, Art. 7.

243 *Id.*, Art. 14.

244 See the description of the LOHAFEX debate within Germany in Chapter 6. For more on nonbinding multilateral environmental agreements, see section 3.5 below.

245 Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Ninth Meeting (2008), Decision IX/16 C.4.

246 Report of the Tenth Meeting of the Conference of Parties to the Convention on Biological Diversity (2010), Decision X/33.8(w). Art. 3 is the restatement of a state's right to exploit its natural resources and its responsibility to prevent transboundary harm.

247 *Id.*, fn. 76.

248 Secretariat of the CBD, *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters*, (Montreal: Secretariat of the CBD, 2012), 8.

249 Report of the Eleventh Meeting of the Conference of Parties to the Convention on Biological Diversity (2012), Decision XI/20; Conference of the Parties to the Convention on Biological Diversity (2016), Climate-related geoengineering, Decision XIII/14.

250 Conference of the Parties to the Convention on Biological Diversity (2016), *supra* note 249, para. 5.

251 *Id.*, Decision XI/20, para. 8; Regulatory Framework for Climate-related Geoengineering Relevant to the Convention on Biological Diversity (2012), 6; Williamson and Bodle, *supra* note 240, at 12. Deference to the London Convention and London Protocol is reinforced by CBD, Art. 22, in which Parties agree to implement the CBD "with respect to the marine environment consistently with the rights and obligations of States under the law of the sea."

252 Williamson and Bodle, *supra* note 240, at 144.

253 CBD, Art. 14.1.

254 However, the COP report noted "that the call for a moratorium on ocean fertilization would be implicit." Report of the COP to the CBD at its 9th Meeting, *supra* note 170, para. 250. *See* Jesse L. Reynolds, Andy Parker, and Peter Irvine, *Five Solar Geoengineering Tropes that Have Outstayed Their Welcome*, 4 EARTH'S FUTURE 562 (2016).

255 Masahiro Sugiyama and Taishi Sugiyama, *Interpretation of CBD COP10 Decision on Geoengineering* (Socio-economic Research Center, Central Research Institute of Electric Power Industry, 2010), 1.

256 Statement by the IOC ad hoc Consultative Group on Ocean Fertilization, Submitted by the Intergovernmental Oceanographic Commission (IOC) (2008), Addendum (June 14, 2008).

257 Secretariat of the CBD, *supra* note 248; Williamson and Bodle, *supra* note 240.
258 More accurately, the land area is subject to claims by seven states, but these are not fully recognized and further claims are prohibited by the Antarctic Treaty.
259 Michael C MacCracken, *On the Possible Use of Geoengineering to Moderate Specific Climate Change Impacts*, 4 Environmental Research Letters 045107 (2009); John Latham et al., *Marine Cloud Brightening: Regional Applications*, 372 Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sicences 20140053 (2014).
260 The Antarctic Treaty (1959), Arts. II–III.
261 *Id.*, Art. IX.
262 *Id.*, Art. I.
263 Protocol on Environmental Protection to the Antarctic Treaty (1991), Art. 2.
264 *Id.*, Art. 3.1.
265 *Id.*, Art. 3.3.
266 *Id.*, Art. 3.2(a).
267 *Id.*, Art. 3.2(b).
268 *Id.*, Art. 3.2(c).
269 *Id.*, Arts. 3.2(d)–(e), 6, 8, 17, Annex I.
270 *Id.*, Annex II, Arts. 1, 3; Annex V, Art. 4.
271 *Id.*, Annex IV, Arts. 4, 11.
272 For example, France is the nonparty state with the largest economy.
273 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques [hereinafter ENMOD] (1977), Art. II.
274 *Id.*, Art. I.1.
275 Understandings Regarding the Convention, Report of Conference of the Committee on Disarmament, General Assembly Official Records (1976).
276 ENMOD, Art. III.1.
277 *Id.*, Preamble.
278 *Id.*, Art. III.2.
279 *See* The UN Office at Geneva, Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD), www.unog.ch/enmod.
280 Convention on International Civil Aviation [hereinafter Chicago Convention] (2006), Art. 1.
281 *Id.*, Art. 2.
282 *Id.*, Arts. 17–21, 29–36; Convention on Offences and Certain Other Acts Committed on Board Aircraft (1963), Art. 3.
283 Chicago Convention, Arts. 3, 5. The aims of the Chicago Convention are unstated beyond the Preamble's exhortations regarding "friendship and understanding among the nations and peoples of the world," the desire "to avoid friction and to promote … cooperation between nations and peoples," and the goal to develop civil aviation "in a safe and orderly manner." However, the aims of the International Civil Aviation Organization are enumerated, including ensuring "the safe and orderly growth of international civil aviation throughout the world" and meeting "the needs of the peoples of the world for safe, regular, efficient and economical air transport." Here, "safe" could include protection from environmental harm. *See id.*, Art. 44.

284 *Id*., Arts. 3(c), 6, 8.
285 *Id*., Art. 12.
286 *Id*., Art. 11.
287 *Id*., Arts. 12, 37, 43–79.
288 *Id*., Art. 38.
289 International Civil Aviation Organization, *Environmental Protection, Volume II: Aircraft Engine Emissions*, Third edn (2008).
290 For example, the state could claim that the emissions are not safe. Such a state could make other claims, such as those concerning transboundary harm, if its environment were impacted by the emissions, and those concerning violations of sovereignty.
291 Chicago Convention, Art. 3 *bis*.
292 Convention on Offences and Certain Other Acrs Committed on Board Aircraft, Art. 4.
293 Chicago Convention, Arts. 3 *bis*, 4.
294 *Id*., Arts. 84–88.
295 The L1 Lagrangian point is the location between the Earth and the Sun where their gravitational forces are counterbalanced by the centripetal (center-seeking) force required for an object to orbit the sun. An object there would consequently also be directly between the Earth and the Sun. This is approximately 1 percent of the distance from the Earth to the Sun, or about four times the distance from the Earth to the Moon.
296 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies [hereinafter Outer Space Treaty] (1967), Arts. I, III, IX. Note that a subsequent UN General Assembly resolution clarified that the first cited phrase was intended to encourage consideration of developing countries' needs and to stimulate cooperation. *See* Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interests of All States Taking into Particular Account the Needs of Developing Countries, UNGA Res 122 (LI) (1996).
297 Outer Space Treaty, Art. XI.
298 *Id*., Art. VI.
299 *Id*., Art. I.
300 *Id*., Art. VII; Convention on International Liability for Damage Caused by Space Objects (1972), Arts. I(c), II.
301 *Id*., Art. V.1.
302 UN Economic and Social Council, Substantive Issues Arising in the Implementation of the International Covenant on Economic, Social and Cultural Rights: General Comment 12 (U E/C.12/1999/5) (1999), 4–5.
303 International Covenant on Economic, Social and Cultural Rights [hereinafter ICESCR] (1966), Art. 11. Note that the USA is not a party to this treaty.
304 *Id*., Arts. 11–12. *See* Han Somsen, *Towards a Law of the Mammoth? Climate Engineering in Contemporary EU Environmental Law*, 7 European Journal of Risk Regulation 109 (2016).
305 United Nations Universal Declaration on Human Rights, UNGA Res 217 A [hereinafter UDHR] (1948), Arts. 19, 26, 27; International Covenant on Civil and Political Rights [hereinafter ICCPR] (1966), Art. 19; ICESCR, Arts. 13, 15; Charter of Fundamental Rights of the European Union (2000), Art. 13. *See* Rhona K. M.

Smith, *Textbook on International Human Rights*, Seventh edn (Oxford: Oxford University Press, 2016), 339. *See also* Antarctic Treaty, Art. II; Outer Space Treaty, Art. I; UNCLOS, Art. 238.

306 ICESCR, Art. 15.1(c). *See* subsection 3.4.4.

307 UDHR, Art. 27(1); ICESCR, Arts. 15.1(b), 15.2; Farida Shaheed, Report of the Special Rapporteur in the Field of Cultural Rights, Farida Shaheed: The Right to Enjoy the Benefits of Scientific Progress and Its Applications (A/HRC/20/26) (2012).

308 Rio Declaration, A/RES/47/190, Principle 10. *See also* World Charter for Nature, UNGA Res 37/7 (1982), Princ. 23; Neil Craik, *International EIA Law and Geoengineering: Do Emerging Technologies Require Special Rules?*, 5 CLIMATE LAW 111 (2015).

309 UDHR, Art. 19; ICCPR, Art. 19.2. These include a "freedom to seek, receive and impart information and ideas." The precise contours of states' concomitant duties to fulfill this right are unclear.

310 *See* the discussion of the Aarhus Convention, subsection 3.3.3.2, and of customary international law, subsection 3.6.2, as well as UNFCCC, Art. 4.1(i).

311 *See* World Conference on Science, Declaration on Science and the Use of Scientific Knowledge (1999), para. 41; Anna-Maria Hubert *Code of Conduct for Responsible Geoengineering*: www.ucalgary.ca/grgproject/files/grgproject/revised-code-of-conduct-for-geoengineering-research-2017-hubert.pdf

312 *See* Chapter 6.

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314 Agreement Establishing the World Trade Organization, Annex 1C, Agreement on Trade-Related Aspects of Intellectual Property Rights (1994), Art. 31.

315 *Id.*, Art. 27.2.

316 Charter of the United Nations, Chapter IV.

317 *Id.*, Chapters V, VII.

318 Statute of the International Court of Justice (1945).

319 Declaration of the United Nations Conference on the Human Environment [hereinafter Stockholm Declaration] (1972), Preamble, Proclamations 3, 6.

320 *Id.*, Principle 1.

321 *Id.*, Principle 18. *See also* Principle 20.

322 *Id.*, Principles 21, 24.

323 A/RES/47/190.

324 Rio Declaration, Principle 1.

325 *Id.*, Principles 2, 3.

326 *Id.*, Principle 9.

327 *Id.*, Principle 14.

328 *Id.*, Principles 1, 3, 7, 10, 15–17, 19, 27. *See* sections 3.6 and 3.7.

329 Johannesburg Declaration on Sustainable Development (2002), Annex.

330 The Future We Want (2012), para. 167.

331 The 2030 Agenda for Sustainable Development (2015).

332 *Id*., Preamble para. 31.
333 *Id*., target 13.3.
334 Provisions for Co-operation between States in Weather Modification (1980), footnote.
335 *Id*., para. 1(a).
336 *Id*., para. 1(h).
337 *Id*., para. 1(b).
338 *Id*., para. 1(c)–(d).
339 *Id*., para. 1(e)–(f).
340 *See* Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 Michigan Journal of International Law 309, 328 (2013).
341 UNESCO Expert Meeting, *Geoengineering: The Way Forward?* (November 2010), www.unesco.org/new/en/natural-sciences/about-us/single-view/news/geoengineering_the_way_forward/.
342 The World Climate Research Programme was established in 1980 by the International Council for Science and the WMO. Now with the additional sponsorship of the IOC of UNESCO, it is a leading international coordinator of climate research.
343 *See* UNESCO Expert Meeting, *supra* note 341.
344 *Engineering the Climate: Research Questions and Policy Implications*, UNESCO SCOPE UNEP Policy Briefs No. 14 (2011).
345 Doug Wallace et al., *Ocean Fertilization: A Scientific Summary for Policy Makers* (UNESCO 2010).
346 WMO, Report of the Expert Team on Weather Modification Meeting, Phitsanulok, Thailand, 17–19 March 2015, at 7, www.wmo.int/pages/prog/arep/wwrp/new/documents/WMO_expert_mtg_Phisanulok_2015_report_FINAL.pdf. The American Meteorological Society statement concludes: "The potential to help society cope with climate change and the risks of adverse consequences imply a need for adequate research, appropriate regulation, and transparent deliberation." AMS, Geoengineering the Climate System: A Policy Statement of the American Meteorological Society, www2.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/geoengineering-the-climate-system/. *See also* Alan Robock and Roelof Bruintjes, WMO Statement on Geoengineering: Draft, www.wmo.int/pages/prog/arep/wwrp/new/documents/WMO_Statement_Geoengineering.pdf.
347 *See* WMO, Report of the Expert Team on Weather Modification Meeting, *supra* note 346, at 14.
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357 International Court of Justice, *Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion*, International Court of Justice Reports 226 (1996).
358 Rio Declaration, Principle 2.
359 *See* Kerryn Brent, Jeffrey McGee, and Amy Maguire, Does the "No-Harm" Rule Have a Role in Preventing Transboundary Harm and Harm to the Global Atmospheric Commons from Geoengineering?, 5 *Climate Law* 35 (2015).
360 International Law Commission, Prevention of Transboundary Harm from Hazardous Activities, in *Official Records of the General Assembly, Fifty-sixth Session*, Supplement No. 10 (A/56/10) (2001), Arts. 1, 2(a). Note that the ILC Articles are not themselves legally binding, but instead represent experts' best effort to capture current custom as practiced by states.
361 *Id.*, Arts. 3–4, 6–8, 13, 16.
362 *Id.*, Art. 9.
363 *Id.*, Art. 10(b), (e).
364 *See* David Reichwein et al., State Responsibility for Environmental Harm from Climate Engineering, 5 *Climate Law* 142 (2015).
365 International Law Commission, Prevention of Transboundary Harm, *supra* note 360, Art. 9.3.
366 Reichwein et al., *supra* note 364, at 169–70. *See also* Brent, McGee, and Maguire, *supra* note 359.
367 *See* Birnie, Boyle, and Redgwell, *supra* note 17, at 180–82, esp. footnote 440, citing the version found in the Sixth Report on International Liability for Injurious Consequences Arising out of Acts Not Prohibited by International Law (1990), Art. 20.
368 Bodansky, *supra* note 3, at 312; Reichwein et al., *supra* note 364, at 180.
369 Daniel Bodansky, *Governing Climate Engineering: Scenarios for Analysis*, 11–47 The Harvard Project on Climate Agreements Discussion Papers (2011), 15.
370 René Lefeber, *Climate Change and State Responsibility*, in International Law in the Era of Climate Change (Rosemary Rayfuse and Shirley V. Scott Cheltenham, eds., Cheltenham: Edward Elgar, 2012), 333–40.
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373 International Law Commission, *supra* note 371, Arts. 1–2, 30–31.

374 *Id.*, Arts. 34–37.

375 *See* Chapter 5 on liability.

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380 *See* Eva M. Kornicker Uhlmann, *State Community Interests, Jus Cogens and Protection of the Global Environment: Developing Criteria for Peremptory Norms*, 11 Georgetown International Environmental Law Review 101 (1998); Lefeber, *supra* note 370, at 342–33.

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384 International Law Commission, *supra* note 371, Art. 49.

385 *Id.*, Art. 54.

386 UNFCCC, Preamble para. 1. *See* Dinah Shelton, *Common Concern of Humanity*, 5 *Iustum Aequum Salutare* 33, 39 (2009).

387 International Law Commission, *supra* note 371, Art. 52.

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389 *Id.*, Art. 53.

390 *Id.*, Art. 49.

391 *Id.*, Art. 49, commentary (4).

392 *Draft Principles on the Allocation of Loss in the Case of Transboundary Harm Arising out of Hazardous Activities, with Commentaries*, in Report of the International Law Commission, 58th session, Official Records of the General Assembly (United Nations, 2006), Principles 1–2. Environmental damage to areas beyond national jurisdiction are not covered.

393 *Id.*, Principle 5.

394 *Id.*, Principle 4.1.

395 *Id.*, Principle 4, 6.

396 *Id.*, Principle 7. *See* Joshua B. Horton, Andrew Parker, and David Keith, Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities, 22 *NYU Environmental Law Journals* 225 (2015); Jesse Reynolds, An Economic Analysis of Liability and Compensation for Harm from Large-Scale Solar Climate Engineering Field Research, 5 *Climate Law* 182 (2015).

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399 Report of the International Law Commission, *supra* note 20, Guideline 7.

400 *Id.*, at 294.

401 *Id*.

402 CBD, Preamble para. 3; UNFCCC, Preamble para. 1.

403 UNCLOS, Art. 194(1); Montreal Protocol, Art. 5; Rio Declaration, Principle 7; CBD, Preamble para. 3; UNFCCC, Arts. 3.1, 4.1; Kyoto Protocol.

404 UNFCCC, Art. 3.1.

405 Paris Agreement, Art. 1.2(a).

406 UNFCCC, Art. 4.1(g); Paris Agreement, Art 10.2.

407 Rio Declaration, Principle 15; CBD, Preamble para. 9; UNFCCC, Art. 3.3; Oslo Protocol, Preamble paras. 3–4; London Protocol, Article 3.1; Kiev Protocol, Art. 3.4.

408 UNFCCC, Art. 3.3.

409 Jesse L. Reynolds and Floor Fleurke, *Climate Engineering Research: A Precautionary Response to Climate Change?*, 7 Carbon and Climate Law Review 101 (2013). *See also* Elizabeth Tedsen and Gesa Homann, *Implementing the Precautionary Principle for Climate Engineering*, 7 Carbon and Climate Law Review 90 (2013); Reichwein et al., *supra* note 364, at 172–3.

410 Res. LC-LP.2; London Protocol.

411 This may be because, in some cases, following the polluter pays principle would be contrary to the public interest. In the international context, side payments to actual and potential polluters is inconsistent with the principle, yet encourages the participation of these often necessary states. In the case of climate engineering, requiring the implementing state or other actor of climate engineering to be responsible for damages may create disincentives for it to undertake an action that offers large net benefits, despite its harm.

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413 *See* Chapter 5.

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