10-2024

Legal Considerations for Atmospheric Methane Removal

Korey Silverman-Roati
Columbia Law School, Sabin Center for Climate Change Law, kgs2133@columbia.edu

Romany M. Webb
Columbia University, Sabin Center for Climate Change Law, rwebb@law.columbia.edu

Legal Considerations for Atmospheric Methane Removal

Korey Silverman-Roati and Romany M. Webb,[1] Columbia University

The authors are solely responsible for the content of this paper, which does not necessarily represent the views of the National Academies of Sciences, Engineering, and Medicine.

This paper does not reflect the views of Columbia Law School or Columbia University. This paper is an academic study provided for informational purposes only and does not constitute legal advice. Transmission of the information is not intended to create, and the receipt does not constitute, an attorney–client relationship between sender and receiver. No party should act or rely on any information contained in this paper without first seeking the advice of an attorney.

1. INTRODUCTION

Developing and, if appropriate, deploying atmospheric methane removal approaches will require an understanding of relevant legal considerations and governing structures that could impact whether, when, where, and how specific projects take place. This paper examines the treatment of atmospheric methane removal approaches under international and U.S. domestic law. Other countries' domestic laws are not discussed. The paper focuses on five atmospheric methane removal approaches that are currently being investigated: (1) atmospheric oxidation enhancement (AOE), (2) ecosystem uptake enhancement, (3) surface treatments, (4) methane reactors, and (5) methane concentrators. Scientists often divide the five approaches into two broad categories based on whether they involve "open" systems (i.e., approaches 1 to 3 above) or "closed" ones (i.e., approaches 4 and 5). This paper adopts that categorization but also distinguishes between approaches based on other factors that are legally significant (see Section 2). The paper does not discuss techniques for reducing methane emissions (e.g., flaring or other techniques that address high-concentration streams) and does not cover hydrogen emissions,

---

[1] Webb has received research funding from ClimateWorks Foundation and Spark Climate Solutions. She has served in advisory roles for developing codes of conduct for ocean carbon dioxide removal research for the Aspen Institute and GEOMAR, served on an AGU panel to update the union's Position Statement on Climate Interventions, and served on the international advisory committee of the Global ONCE project. Webb has provided paid consulting services to Frontier, Quadrature foundation, and the Carbon to Sea Initiative.

even though they can affect atmospheric methane levels. Instead, this paper focuses on the removal of methane from the atmosphere and related legal issues.

There is no specific legal framework governing atmospheric methane removal activities either at the international level or domestically in the United States. That does not, however, mean that such activities occur in a legal vacuum. They may be subject to a variety of international and domestic laws based on the activities involved and/or their collateral environmental or other impacts. The same is true of many other negative emissions technologies (NETs), and, where relevant, this paper analogizes to the regulation of NETs.

This paper provides an overview of key legal issues relating to atmospheric methane removal research and deployment. With respect to atmospheric methane removal research, the focus is on legal issues associated with activities taking place in the field (i.e., not laboratory research). As research moves into the field, researchers will need to ensure that their projects comply with relevant legal frameworks that will determine whether, when, where, and how such projects may go forward. This paper serves as an initial scoping of those legal frameworks. As stated above, the paper discusses international law and domestic U.S. law, with a particular focus on U.S. federal law. While tribal, state, and local laws also may have implications for atmospheric methane removal projects, a full analysis of those laws is beyond the scope of the paper. Since the focus of the paper is on legal issues relating to atmospheric methane removal, policy considerations are not discussed either. Thus, further research is needed to define the full legal and policy landscape applicable to atmospheric methane removal activities.

The paper begins, in Section 2, with a discussion of the key characteristics of different atmospheric methane removal activities and how those characteristics might impact, or be impacted by, relevant legal frameworks. Section 3 then analyzes the international legal framework governing atmospheric methane removal activities, including the treatment of atmospheric methane removal under the Paris Agreement and international legal decisions governing "geoengineering." Section 4 discusses applicable U.S. domestic law. It is divided into four subsections: the first focuses on crosscutting legal considerations relevant to all atmospheric methane removal approaches; the second and third focus on issues specific to open versus closed system approaches, respectively; and the fourth focuses on liability considerations. Section 5 concludes the paper.

2. LEGAL CATEGORIZATION OF ATMOSPHERIC METHANE REMOVAL ACTIVITIES

This section explains distinctions between different atmospheric methane removal activities and why they might be important from a legal perspective. A key focus is on how the legal considerations relating to atmospheric methane removal activities might change if they involve open versus closed systems. This is addressed in Section 2.1. Section 2.2 discusses an alternative approach to categorizing atmospheric methane removal activities based on where they occur (i.e., whether they take place on land or in the ocean). The subsection explains why

location is important from a legal perspective and describes relevant jurisdictional boundaries—state borders, state ocean waters, federal ocean waters, and the high seas—that need to be considered when evaluating the legal frameworks applicable to atmospheric methane removal activities. Section 2.3 discusses relevant legal distinctions between research and deployment activities.

2.1 Legal Implications of Testing and Deploying Open versus Closed Atmospheric Methane Removal Systems

Atmospheric methane removal systems may be categorized based on whether they involve open or closed systems. The defining distinction between these categories is whether the underlying systems include a physical barrier separating atmospheric methane removal reactions from natural environments (e.g., the atmosphere). Open systems do not include a physical barrier, and thus their impacts are likely to be diffuse over a given geographical area. Closed systems include a physical barrier, meaning that their reactions and impacts will occur within a physically bounded area.

Open system approaches to atmospheric methane removal include the following:

- *AOE*, which involves increasing the removal of methane via the augmented abundance or lifetime of reactive species, such as chloride or hydroxyl radicals, in the troposphere and stratosphere of the Earth's atmosphere. To increase the reactive species, aerosols (e.g., iron, titanium dioxide, zinc oxide, or hydrogen peroxide) might be released from towers on land or the ocean or via exhaust from planes or other vehicles. In the latter case, substances (e.g., iron additives) would be added to vehicle fuels, which when combusted would produce exhaust that would increase the abundance of the reactive species.
- *Surface treatments,* which involve the application of a catalytic species that enhances the destruction of methane at or near a surface (e.g., photocatalytic paints). These might be deployed on building walls and roofs.
- *Ecosystem uptake enhancement*, which involves an amendment or practice that augments the removal of methane by or within natural systems. One way to do this is by applying organic materials (e.g., biochar, compost, or sewage) or other soil amendments (e.g., copper or silicate dust) to agricultural lands. It might also be possible to engineer bacteria to better oxidize methane in soils.

While all open systems share certain similarities, there are also important differences between them—for example, in terms of where they might be deployed and the nature and location of their potential impacts. Different open system approaches may, therefore, be subject to different legal frameworks. For instance, agricultural laws might apply to ecosystem uptake enhancement approaches but likely not to AOE approaches occurring in the ocean. Nevertheless, many open system approaches will raise similar legal issues. As an example, open systems are

more likely to have diffuse impacts that may implicate cross-jurisdictional legal regimes, including international laws prohibiting transboundary environmental harm. They are also more likely to implicate international, federal, and state laws governing use of the ocean. Environmental review requirements for open systems are likely to require consultation with a wider array of potentially impacted groups. And given the potential for widespread impacts from open systems, they may have greater liability exposure (e.g., because more people might be harmed by their use).

Closed atmospheric methane removal systems include the following:

- *Methane reactors,* which are physically bounded systems open to the flow of air that convert methane to a different chemical species (e.g., carbon dioxide [CO_2], methanol, or polymeric substance).
- *Methane concentrators*, which are materials or reactors that can separate or enrich methane with some degree of selectivity relative to other atmospheric components (e.g., polymeric substances that can separate methane from a dilute stream).

Theoretically, closed atmospheric methane removal systems could be sited anywhere on land, although some projects may require large amounts of energy and thus ideally would be sited alongside renewable energy systems.

Given the physical barriers separating closed systems from their surroundings, and the resulting limitations in the geographic range of their impacts, the legal framework applicable to these systems will often be less complex and implicate fewer jurisdictions. Key legal considerations will govern land acquisition to place the systems and assessment of their impacts, especially any air and water pollution impacts. U.S. state and local laws where these systems are located will likely be especially important. Given this, project proponents of closed systems may have more flexibility to choose states with favorable legal frameworks for field testing and deployment.

2.2 Legal Implications of Testing and Deploying Systems on Land versus in the Ocean

Where atmospheric methane removal activities occur will also affect the applicable laws. Particularly important is whether activities will be performed on land or take place in, or affect, the ocean. Certain international legal frameworks, like the United Nations Convention on the Law of the Sea (UNCLOS), only apply to certain activities taking place in or affecting the marine environment.[2] Similarly, in the United States, laws like the Marine Protection, Research

[2] UNCLOS does not define the term "marine environment," but in its 2024 advisory opinion on climate change, the International Tribunal for the Law of the Sea found that UNCLOS refers to the marine environment "in a general sense" and clarified that "[t]he term 'marine' means belonging to, existing or found in, or produced by, the sea; belonging to, or situated at, the sea-side, bounded by the sea. The term 'environment' denotes the area surrounding a place or thing; the surroundings or physical context and conditions in which an organism lives, develops, or a thing

and Sanctuaries Act (MPRSA) only apply to certain ocean-based activities. Distinctions between ocean and land areas further divide applicable jurisdictions and legal frameworks.

2.2.1 Activities on Land

In the United States, jurisdiction over land-based activities is divided between federal, tribal, state, and local authorities. Federal environmental law, which is constitutionally justified as an exercise of the federal government's authority to regulate interstate commerce,[3] is likely to apply to atmospheric methane removal activities regardless of the state in which they take place. The location of activities will, however, impact the nonfederal laws that apply. Differing state laws governing activities associated with atmospheric methane removal could have a significant impact on project costs and timelines. This has already been seen in the context of carbon dioxide removal (CDR) projects (Pacyniak, 2023; Parker, 2022; Silverman-Roati et al., 2022a).

Project proponents should also be cognizant of land use, environmental, and other rules that may be imposed by local governments and Native American tribes. Although it is beyond the scope of this paper, further research on comparative legal regimes in states, localities, and tribes across the country is likely to help project proponents in site selection.

2.2.2 Activities in the Ocean

Jurisdiction over ocean-based activities depends on how far off shore the activities occur. At the international level, UNCLOS divides ocean waters and the underlying submerged land into several zones, each of which has a different jurisdictional status. At the time of writing, 167 countries and the European Union (EU) had ratified UNCLOS (UN, 2023b). The United States had not but recognizes many of its provisions, including those discussed here, as forming part of customary international law (UN, 2023b; U.S. Department of State, n.d.-a).

Under UNCLOS, coastal countries generally have jurisdiction over ocean areas within 200 nautical miles (nm) of the "baseline" (normally, the low water line along their coasts) and further in some cases.[4] Ocean waters extending 12 nm from the baseline comprise the territorial sea and are considered part of the sovereign territory of the coastal country (Figure 1). Each coastal country has full sovereignty over the waters within, the seabed below, and the airspace above its territorial sea, subject to UNCLOS and other rules of international law.[5] Waters extending beyond the territorial sea, up to 200 nm from the baseline, make up the exclusive economic zone (EEZ).[6] The EEZ is not sovereign territory, but coastal countries do have sovereign rights to explore, exploit, conserve, and manage natural resources in their EEZs and to

---

exists; the external conditions in general affecting the life, existence, or properties of an organism or object." Request for an Advisory Opinion Submitted by the Commission of Small Island States on Climate Change and International Law, Advisory Opinion, ITLOS, paras. 166–167 (May 21, 2024) (hereinafter ITLOS Advisory Opinion on Climate Change).

[3] Zabel v. Tabb, 430 F.2d 199, 206 (5th Cir. 1970).

[4] United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397 (hereinafter UNCLOS).

[5] UNCLOS, Art. 2–3.

[6] UNCLOS, Art. 55 & 57.

undertake other activities for the economic exploitation of the zone. Coastal countries can establish artificial islands and other structures, conduct marine scientific research (MSR), and engage in other activities for the protection and preservation of the marine environment in their EEZs.[7] The submerged land underlying a country's EEZ is known as its continental shelf; in some situations, a country's continental shelf may extend more than 200 nm from its coast.[8] Each coastal country has sovereign rights over its continental shelf for the purpose of exploring and exploiting the shelf's natural resources.[9]

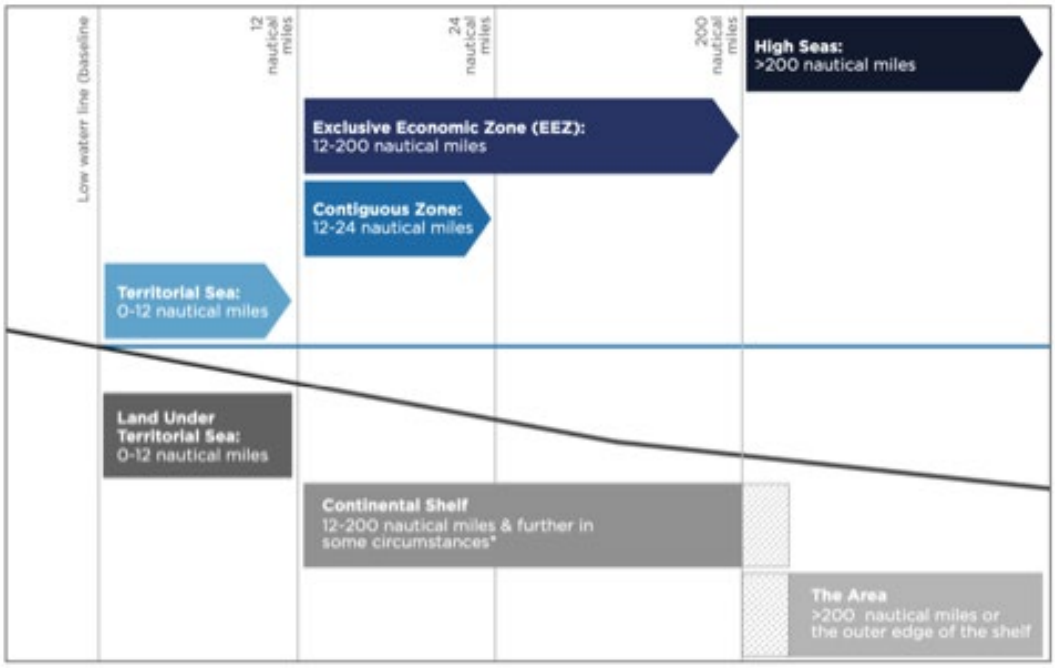

FIGURE 1 Offshore zones identified in the United Nations Convention on the Law of the Sea. SOURCE: Webb et al., 2022.

Ocean waters more than 200 nm from shore are known as the high seas and are open to use by all coastal and landlocked countries in accordance with international law.[10] A country's domestic laws may apply to activities on the high seas if they are performed by individuals subject to that country's jurisdiction (e.g., because the individual is a national of the country) or using vessels that are registered or flagged in the country.

---

[7] UNCLOS, Art. 56.

[8] A country's continental shelf may extend beyond 200 nm from the baseline to the outer edge of the continental margin, up to 60 nm from the foot of the continental shelf or the point where sediment thickness is 1% of the distance thereto. Notably, however, the continental shelf cannot extend more than 100 nm from the 2,500-meter isobath or 350 nm from the baseline. UNCLOS, Art. 76.

[9] UNCLOS, Art. 77.

[10] UNCLOS, Art. 86–87.

Within the U.S. territorial sea and EEZ, jurisdiction is shared among the coastal states and territories and the federal government. Offshore waters within 3 nm of shore (and further in some cases) as well as the underlying submerged land fall under the primary jurisdiction of the relevant coastal state or territory.[11] However, the federal government retains authority to regulate state waters and the underlying submerged land "for the constitutional purposes of commerce, navigation, national defense, and international affairs."[12] This includes the constitutional justification for federal environmental laws, so those laws may apply to state ocean waters. Local governments also have limited authority in state waters in some areas. Waters lying beyond state boundaries up to 200 nm from shore fall under the exclusive authority of the federal government. The seabed underlying federal waters, known as the outer continental shelf, is also federally controlled.

2.3 Legal Implications of Conducting Field Research versus Deployment Activities

Whether an atmospheric methane removal activity is conducted for research purposes or as part of a commercial deployment may also affect the laws that apply. Distinguishing between research and deployment is often difficult. Generally speaking, research typically involves size- or time-limited projects that are aimed at answering specific scientific or technical questions or testing a particular hypothesis; deployments tend to involve larger-scale or longer implementations, the primary purpose of which is not advancement of scientific understanding. However, some research projects may involve relatively large or long-duration field trials that must, necessarily, take place in the open. The dividing line between that kind of research and small-scale deployments is often blurry. In other contexts, regulators have sought to define size limits or other clear thresholds for research versus deployment. For example, in its Directive on the Geological Storage of Carbon Dioxide, the EU defined research projects as those involving "total intended storage below 100 kilotonnes" of CO_2.[13] Defining similar thresholds for atmospheric methane removal research may be helpful.

Many of the laws applicable to atmospheric methane removal activities do not establish separate rules for research versus deployment, but some do distinguish between the two activities. Most notably, various international laws governing ocean-based activities establish specific permitting and other requirements for research projects. One example is UNCLOS, discussed in more detail in Section 3 below, which establishes specific rules for MSR.[14] UNCLOS does not define MSR, but several legal scholars have concluded that the rules would

---

[11] Texas and Florida have jurisdiction over areas extending 9 nm from shore in the Gulf of Mexico. The jurisdiction of Puerto Rico also extends 9 nm from shore. See 43 U.S.C. §§ 1301 & 1312; 48 U.S.C. 1705; U.S. v. Louisiana [1980] 100 S. Ct. 1618, 420 US 529 [1975], 394 US 11 [1969], 389 US 155 [1967], 363 US 1 [1960], 339 US 699 [1950].

[12] 43 U.S.C. § 1314.

[13] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the Geologic Storage of Carbon Dioxide and Amending Council Directive 85/227/EEC; European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC, and Regulation (EC) No 1013/2006.

[14] UNCLOS, Part XIII.

apply to demonstration or testing of ocean CDR approaches if conducted "in situ" in the ocean (Brent et al., 2019; Proelss & Hong, 2012; Stephens & Rothwell, 2016). The rules would similarly likely apply to demonstration and testing of atmospheric methane removal techniques in the ocean. In general, UNCLOS recognizes that each coastal country has "the right to regulate, authorize, and conduct" MSR within its territorial sea and EEZ.[15] Both coastal and landlocked countries also have a right to conduct MSR on the high seas. If countries want to conduct MSR in the territorial sea and EEZ of another country, they must obtain that country's consent, and consent may only be withheld if certain conditions set out in UNCLOS are met.[16] Countries must ensure that all MSR (regardless of where it occurs) is conducted in accordance with "appropriate scientific methods" and in a manner that does not "unjustifiably interfere with other legitimate uses of the ocean."[17]

The parties to other international agreements—for example, the Convention on Biological Diversity (CBD) and the London Convention and Protocol—have adopted decisions on ocean fertilization and geoengineering that seek to distinguish between research and deployment.[18] The decisions, discussed in more detail in Section 3 below, are nonbinding but highly influential. In general, they aim to prevent deployment of ocean fertilization and other geoengineering techniques, and establish requirements for conducting scientific research thereon.

The decisions adopted under the CBD do not define what constitutes "research" but state that research projects should be "small scale" and impose restrictions on where and how they can take place.[19] In contrast, the London Convention and Protocol decisions do not establish any size thresholds for research but instead focus on the purpose for which an activity is being undertaken. Under the London Convention and Protocol decisions, for an activity to qualify as "legitimate scientific research," it must meet the following requirements:

- the activity "should be designed to answer questions that will add to the body of scientific knowledge";
- "economic interests should not influence the design, conduct, and/or outcomes of the [activity]," and "[t]here should not be any financial and/or economic gain arising directly from" the activity;
- the activity "should be subject to peer review at appropriate stages"; and

---

[15] UNCLOS, Art. 245–246.

[16] UNCLOS, Art. 238, 245, 246, 256, & 257. The conditions for withholding consent are that the project (a) is of direct significance for the exploration and exploitation of natural resources; (b) involves drilling into the continental shelf, the use of explosives, or the introduction of harmful substances into the marine environment; (c) involves the construction, operation, or use of artificial islands, installations, and structures; or (d) contains inaccurate information or the research sponsor has outstanding obligations from a prior research project.

[17] UNCLOS, Art. 240.

[18] See, for example, Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Ninth Meeting, Decision IX/16, Art. C(4) (2008) (hereinafter 2008 CBD Decision); Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization (Oct. 31, 2008) (hereinafter 2008 LC/LP Resolution).

[19] 2008 CBD Decision, Art. C(4).

- data and outcomes should be "made publicly available" and results published "in peer reviewed scientific publications."[20]

According to the London Convention and Protocol decisions, research projects that meet these requirements may go ahead, provided that they first undergo an environmental assessment and meet certain other requirements.[21] Notably, however, the decisions state that "activities other than legitimate scientific research should not be allowed."[22] This and other examples thus imply that where legal regimes distinguish between research and deployment, they tend to impose greater restrictions on deployment activities. Moreover, even where legal requirements apply broadly to both research and deployment, the latter may be subject to greater legal scrutiny if it has the potential for more widespread and/or serious environmental or other impacts.

3. INTERNATIONAL LAW RELEVANT TO ATMOSPHERIC METHANE REMOVAL

This section discusses key principles of customary international law and international agreements potentially relevant to atmospheric methane removal activities. At the outset, it is important to note that international agreements impose obligations only on countries that consent to be bound by them. Customary international law, on the other hand, is derived from established international practices that are accepted as law and is binding on all countries. (The only exception is when a country has "persistently objected" to a particular rule and thus may not be required to comply with it [Green, 2016].)

While international law is generally only binding on countries (as distinct from noncountry actors), it may inform domestic regulation and thus have implications for the testing and deployment of atmospheric methane removal approaches by private individuals and companies. For example, customary international law and several international agreements establish baseline requirements for environmental impact assessments (EIAs), which have influenced domestic environmental review processes that atmospheric methane removal projects might be subject to. International law will be particularly relevant to open system atmospheric methane removal projects that result in, or have the potential to result in, transboundary environmental harm since that is a key focus of many international environmental agreements and rules of customary international law.

This section identifies key international law requirements that will apply to atmospheric methane removal activities and highlights important differences in the treatment of different

---

[20] Resolution LC-LP.2(2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization (Oct. 14, 2010) (hereinafter 2010 LC/LP Resolution).

[21] 2010 LC/LP Resolution. The resolution states that countries "should" only allow research projects if "conditions are in place to ensure that, as far as practicable, environmental disturbance would be minimized, and the scientific benefits maximized" and further provides that "[i]f the risks and/or uncertainties [associated with a project] are so high as to be deemed unacceptable, with respect to the protection of the marine environment, taking into account the precautionary approach, then a decision should be made to seek revision of or reject the proposal."

[22] See, for example, 2008 LC/LP Resolution.

approaches (e.g., based on whether they involve open versus closed systems or take place in terrestrial versus ocean environments). It also discusses the impact of "soft law" instruments, including nonbinding resolutions addressing geoengineering activities that have been adopted under the CBD and other international agreements. Finally, the potential for state responsibility if international legal requirements are not met is also explored.

3.1 Relevant Principles of Customary International Law

Atmospheric methane removal activities, especially those involving the use of open system approaches, could implicate the "no harm" rule of customary international law. According to the no harm rule, each country must "ensure that activities within their jurisdiction or control do not cause damage to the environment of other [countries] or of areas beyond the limits of national jurisdiction."[23] The International Tribunal for the Law of the Sea (ITLOS) described the rule as imposing an obligation of "due diligence" on countries to "exercise best possible efforts" or "do the utmost" to avoid or minimize transboundary environmental damage.[24] Countries must, at a minimum, closely oversee activities that could cause transboundary environmental damage (e.g., by adopting and strictly enforcing relevant domestic laws).[25] The International Court of Justice has stated that due diligence "entails not only the adoption of appropriate rules and measures, but also a certain level of vigilance in their enforcement and the exercise of administrative control applicable to public and private operators, such as the monitoring of activities undertaken by such operators."[26] Thus, under the no harm rule, countries have a due diligence obligation to ensure that domestic laws and other measures adequately protect against any adverse transboundary environmental impacts from atmospheric methane removal projects.

Also under customary international law, countries must conduct an EIA before undertaking or authorizing a project that poses a risk of "significant" transboundary environmental damage.[27] There is no agreed upon definition of what constitutes "significant" damage. However, the International Law Commission has interpreted the term as requiring damage that is more than merely "detectable" but not necessarily "serious" or "substantial" (International Law Commission, 2001, p. 152).

Prior to authorizing a project that has the potential to cause transboundary harm, countries must conduct a preliminary assessment to determine whether there is a risk of

---

[23] Declaration of the United Nations Conference on Environment and Development, Principle 2, UN Doc A/CONF.151/26/Rev. 1, June 3–14, 1992.
[24] Responsibilities and Obligations of States Sponsoring Persons and Entities with respect to Activities in the Area, Advisory Opinion, Int'l Tribunal for the Law of the Sea, Case No. 17 at 110 (Feb. 2011) (hereinafter ITLOS Advisory Opinion on Activities in the Area).
[25] ITLOS Advisory Opinion on Activities in the Area at 111–116; Case Concerning Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgement, I.C.J. Rep. 2010 at 187 & 197 (April 2010) (hereinafter Pulp Mills Case).
[26] Pulp Mills Case at 197.
[27] Pulp Mills Case at 204.

significant damage.[28] If this preliminary assessment shows that there is a risk of significant damage, the country must undertake a more comprehensive EIA. Under international law, the country must complete the EIA prior to the commencement of the project but otherwise has broad discretion in conducting the assessment.[29] The United States and many other countries have domestic laws governing the conduct of EIAs. (U.S. requirements are discussed in more detail below.) When the EIA confirms that a project could cause significant transboundary environmental harm, the relevant country must notify and consult with other potentially affected countries and relevant international organizations.[30]

3.2 Relevant International Agreements

3.2.1 United Nations Framework Convention on Climate Change and Paris Agreement

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in May 1992 with the goal of "stabili[zing] greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[31] The UNFCCC entered into force in March 1994 and had been ratified or acceded to by 197 countries and the EU at the time of writing (UN, n.d.-b). In December 2015, the parties to the UNFCCC adopted the Paris Agreement, which aims to "enhance the implementation of" the UNFCCC and thereby "strengthen the global response to the threat of climate change."[32] The Paris Agreement entered into force in November 2016 and had been ratified or acceded to by 195 of the 198 parties to the UNFCCC at the time of writing (UN, n.d.-b).

The United States was the first industrialized country to ratify the UNFCCC in October 1992. The United States adopted the Paris Agreement in September 2016. During the Trump administration, the United States withdrew from the Paris Agreement (with effect from November 4, 2020), but it later rejoined the agreement under President Biden (with effect from February 19, 2021). Both the UNFCCC and Paris Agreement call on parties to mitigate climate change by limiting anthropogenic emissions and enhancing "removals by sinks of greenhouse gases."[33] The term "sink" is defined broadly to mean "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere."[34] The definition is not limited to naturally occurring removals but is broad enough to include those resulting from human interventions (Honegger et al., 2021, p. 328). Many scholars have concluded that the definition captures a wide range of "nature-based" and "engineered" CDR

---

[28] Certain Activities Carried out by Nicaragua in the Border Area (Costa Rica v. Nicaragua), Judgement, ICJ Rep. 2015, 665 at 706–707 (Dec. 2015) (hereinafter Certain Activities Case).
[29] Pulp Mills Case at 204.
[30] Certain Activities Case at 707.
[31] United Nations Framework Convention on Climate, Art. 2, May 9, 1992, S. Treaty Doc No. 102-38, 1771 U.N.T.S. 107 (hereinafter UNFCCC).
[32] Paris Agreement, Art. 2, Dec. 12, 2015, U/N. Doc. FCCC/CP/2-15/L.9/REv/1 (hereinafter Paris Agreement).
[33] UNFCCC, Art. 3; Paris Agreement, Art. 4.
[34] UNFCCC, Art. 1.

approaches (Brent et al., 2019; Craik & Burns, 2016; Honegger et al., 2021; Horton et al., 2016). It could be argued that atmospheric methane removal approaches also fall within the definition (assuming the approaches are effective in removing methane from the atmosphere). There is, however, an important difference between CDR and atmospheric methane removal approaches that might impact their treatment under the UNFCCC and Paris Agreement. Whereas CDR results in the storage of CO_2 outside the atmosphere (e.g., underground or in terrestrial or ocean ecosystems), atmospheric methane removal involves the destruction of methane via oxidation, which typically releases CO_2 that may (or may not) later be removed and stored. Even so, atmospheric methane removal might still be considered "mitigation of climate change" under the UNFCCC and Paris Agreement because it helps to limit near-term warming and thus furthers the goal of avoiding "dangerous anthropogenic interference with the climate system."[35]

The Paris Agreement sets a specific goal of limiting future warming to "well below 2ºC above pre-industrial levels and pursuing efforts to limit [warming] to 1.5ºC above pre-industrial levels."[36] Consistent with that goal, parties to the Paris Agreement aim to achieve net-zero emissions by the second half of the century, meaning that any residual emissions at that time must be offset through removal of greenhouse gases from the atmosphere.[37] In subsequent decisions, the parties have reiterated the urgency of both reducing emissions, including specifically methane emissions, and enhancing removals from the atmosphere. For example, in the 2023 UAE Declaration on Climate and Health, the parties "recognize the need for deep, rapid, and sustained reductions in greenhouse gas emissions in line with 1.5ºC pathways" and, in particular, call for "[a]ccelerating or substantially reducing non-carbon-dioxide emissions, globally, including in particular methane emissions by 2030."[38] The UAE Declaration also calls for "[a]ccelerating zero- and low-emission technologies, including . . . removal technologies."[39]

Each party to the Paris Agreement determines the precise actions it will take to mitigate climate change and details those actions in a "nationally determined contribution" (NDC) that it must submit to the UNFCCC Secretariat in accordance with specified requirements.[40] Parties must periodically update their NDCs to "reflect [the] highest possible ambition."[41] Several parties (including the United States) have outlined, in their most recent NDCs, measures aimed at reducing emissions of methane into the atmosphere. However, to the authors' knowledge, none have proposed removing methane already in the atmosphere. As understanding of atmospheric methane removal develops, parties may look to incorporate atmospheric methane removal into future NDCs. In this regard, it is notable that the United States and several other parties' NDCs already incorporate CDR, with a particular emphasis on nature-based approaches such as forestry and coastal blue carbon (Gallo et al., 2017; Krug, 2018).

---

[35] UNFCCC, Art. 2.
[36] Paris Agreement, Art. 2(1)(a).
[37] Paris Agreement, Art. 4.1.
[38] Outcome of the First Global Stocktake, Draft decision -/CMA.5, FCCC/PA/CMA/2023/L.17 (Dec. 13, 2023).
[39] Outcome of the First Global Stocktake, Draft decision -/CMA.5, FCCC/PA/CMA/2023/L.17 (Dec. 13, 2023).
[40] Paris Agreement, Art. 3 & 4.
[41] Paris Agreement, Art. 4.3.

Under the Paris Agreement, parties may choose to "cooperate in the implementation of their [NDCs]," including through market-based mechanisms. Article 6.2 of the Paris Agreement authorizes parties to enter into bilateral and multilateral agreements to trade emissions reductions and removals (known as internationally transferred mitigation outcomes). Article 6.4 of the Paris Agreement creates a separate, centralized trading mechanism that is governed by the UNFCCC and open to both parties and nonparties (including private sector actors).

Many of the details regarding implementation of Articles 6.2 and 6.4 are still under discussion and not expected to be resolved until 2024 or beyond.[42] One particularly controversial issue relates to the treatment of removal activities under the Article 6.4 mechanism. In May 2023, the subsidiary body appointed by the parties to provide advice on implementing Article 6.4 issued an "information note" on removals:

> there are currently no removal methods for removal of non-CO_2 [greenhouse gases] that have progressed beyond conceptual discussion . . . Some stakeholder submissions [received by the subsidiary body] suggest that [greenhouse gases] other than CO_2 should not be included in the definition of removals.[43]

The subsidiary body noted that common definitions of "removal" (e.g., used by the Intergovernmental Panel on Climate Change) typically refer to activities that remove and durably store CO_2 from the atmosphere and noted that "if the definition were to cover non-CO_2 [greenhouse gases], the word 'storage' might not be appropriate as in the case of [atmospheric methane removal], for example, it may be more appropriate to burn ('destroy') the [methane]".[44] The subsidiary body received many stakeholder submissions on this and related definitional issues. Several of the submissions supported adopting a definition of "removals" that encompasses activities targeting non-CO_2 greenhouse gases. For example, the UK government submitted that there is no "rationale for limiting the type of [greenhouse gas] in the definition at this stage" and expressed concern that doing so "may risk prematurely disincentivizing the development of future [greenhouse gas] removal technologies."[45] It remains to be seen how this and other issues relating to the implementation of Article 6.4 will be resolved.

3.2.2 Convention on Biological Diversity

The CBD aims to promote "the conservation of biological diversity, [and] the sustainable use of its components."[46] The CBD entered into force in December 1993 and had been ratified or otherwise accepted by 195 countries and the EU at the time of writing (UN Environment

---

[42] The parties considered various issues related to implementation of Article 6.2 and 6.4 at COP28 in 2023 but failed to reach agreement on the issuance of guidance therefor.
[43] Information Note: Removal Activities Under the Article 6.4 Mechanism, A6.4-SB005-AA-A09 (2023) at 9.
[44] Information Note: Removal Activities Under the Article 6.4 Mechanism at 10.
[45] Information Note: Compilation of the Public Inputs on Removal Activities under the Article 6.4 Mechanism, A6.4-SB006-AA-A09 (2023) at 23.
[46] Convention on Biological Diversity, May 22, 1992 (hereinafter CBD).

Programme, n.d.). The United States had signed but not ratified the CBD at the time of writing (UN Environment Programme, n.d.).

Article 3 of the CBD recognizes that countries have "the sovereign right to exploit their own resources pursuant to their own environmental policies" but must "ensure that activities within their jurisdiction or control do not cause damage to the environment of other [countries] or of areas beyond the limits of national jurisdiction."[47] Article 7 of the CBD requires parties to, "as far as possible and as appropriate," identify projects "which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity and monitor their effects."[48] Countries will need to be mindful of this requirement when undertaking or authorizing atmospheric methane removal activities as some (e.g., those involving ecosystem uptake enhancement) could affect biodiversity and will thus need to be assessed and closely monitored.

Some atmospheric methane removal techniques could also involve bioengineering—for example, through engineering methane-oxidizing bacteria to better oxidize methane in soil. The CBD obligates parties to "regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts."[49] In 2000, the CBD parties adopted the Cartagena Protocol on Biosafety (Cartagena Protocol), which regulates the transfer, handling, and use of modified organisms. The Cartagena Protocol obligates parties to set out procedures, including advanced informed agreement, in order to ensure safe transfer, handling, and use of modified organisms (Keiper & Atanassova, 2020). At the time of writing, the Cartagena Protocol was in force for 172 countries and the EU, but the United States had not ratified it (UN Environment Programme, 2018).

Other decisions adopted by the parties to the CBD could also have implications for atmospheric methane removal activities. For example, in 2008, the parties adopted a decision dealing with ocean fertilization. Some forms of AOE could result in ocean fertilization and thus implicate the 2008 decision. The decision "requests parties and urges other governments . . . to ensure that ocean fertilization activities do not take place until there is an adequate scientific basis on which to justify such activities."[50] There is an exemption for "small scale research studies within coastal waters," which may be "authorized if justified by the need to gather specific scientific data . . . [and] subject to a thorough prior assessment of the potential impacts of the research studies on the marine environment."[51] According to the 2008 decision, authorized research projects should "be strictly controlled" and not undertaken for any "commercial purpose" (e.g., to sell carbon credits or offsets).[52]

---

[47] CBD, Art. 3.
[48] CBD, Art. 7(c).
[49] CBD, Art. 8(g).
[50] 2008 CBD Decision, Art. C(4).
[51] 2008 CBD Decision, Art. C(4).
[52] 2008 CBD Decision, Art. C(4).

A second decision, dealing with "geoengineering activities," was adopted by the CBD parties in 2010.[53] The decision "invites Parties and other Governments" to consider specified guidelines "on ways to conserve, sustainably use and restore biodiversity and ecosystem services while contributing to climate change mitigation and adaptation."[54] The guidelines recommend that countries do the following:

> Ensure . . . 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[,] . . . 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.[55]

The CBD parties have defined "geoengineering activities" to include any "[d]eliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts."[56] This definition is likely to encompass atmospheric methane removal activities undertaken for the purpose of combating climate change. Thus, according to the 2010 decision, governments should only allow research into atmospheric methane removal in a controlled setting after conducting a comprehensive environmental assessment.

In 2016, the parties to the CBD adopted a decision that, among other things, reaffirmed prior geoengineering decisions and called for more research. The decision notes that "more transdisciplinary research and sharing of knowledge . . . is needed 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."[57]

It should be noted that the decisions referenced above are not legally binding and use fairly soft language (e.g., the 2010 decision "invites" parties to do certain things). Even so, the decisions carry weight and may impact countries' approaches to atmospheric methane removal activities (Proelss & Steenkamp, 2022; Webb et al., 2023).

---

[53] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Tenth Meeting, Decision X/33, Art. 8 (2010) (hereinafter 2010 CBD Decision).
[54] 2010 CBD Decision, Art. 8. The 2010 decision was reaffirmed by the Conference of the Parties to the CBD in 2012 and again in 2016.
[55] 2010 CBD Decision, Art. 8(w).
[56] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Eleventh Meeting, Decision XI/20 (2012).
[57] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Thirteenth Meeting, Decision XIII/14 (2016).

3.2.3 Ocean Agreements

The agreements in this subsection apply to activities occurring in, or affecting, the marine environment.

3.2.3.1 United Nations Convention on the Law of the Sea

UNCLOS defines countries' rights and responsibilities with respect to the management and use of marine areas. UNCLOS was adopted in December 1982 and entered into force in November 1994 (UN, 2023c). As mentioned above, the United States had not ratified UNCLOS at the time of writing, but it recognizes many of UNCLOS' provisions as forming part of customary international law and thus abides by them (UN, 2023b; U.S. Department of State, n.d.-a).

Atmospheric methane removal projects that are conducted in, or could impact, the marine environment would need to comply with Part XII of UNCLOS, which imposes a general obligation on countries to "protect and preserve the marine environment."[58] This general obligation is elaborated on in subsequent provisions of UNCLOS. For example, under Article 194, countries are required 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."[59]

Article 206 of UNCLOS provides that before undertaking any activity that "may cause . . . significant and harmful changes to the marine environment," countries must "assess the potential effects" of the activity and publish the findings of that assessment.[60] Once the activity commences, countries also have a duty to monitor the activity and its effects on the marine environment.[61]

Countries also have an obligation, under Article 194 of UNCLOS, to "take all measures consistent with th[e] Convention that are necessary to prevent, reduce and control pollution of the marine environment."[62] UNCLOS defines "pollution of the marine environment" broadly to mean the introduction of "substances or energy into the marine environment . . . which results or is likely to result in such deleterious effects as" harm to living resources, human health, and marine activities.[63]

In May 2024, ITLOS issued an advisory opinion on climate change and international law, in which the UNCLOS definition of pollution was discussed extensively. ITLOS noted that the UNCLOS definition "does not provide a list of pollutants or forms of pollution of the marine environment. Instead, it sets out three criteria to determine what constitutes such pollution: (1) there must be a substance or energy; (2) this substance or energy must be introduced by humans, directly or indirectly, into the marine environment; and (3) such introduction must result or be

---

[58] UNCLOS, Art. 192.
[59] UNCLOS, Art. 194(5).
[60] UNCLOS, Art. 206.
[61] UNCLOS, Art. 204.
[62] UNCLOS, Art. 194(1).
[63] UNCLOS, Art. 1(1)(4).

likely to result in deleterious effects."[64] Applying these three criteria, ITLOS found that anthropogenic greenhouse gas emissions into the atmosphere constitute marine pollution within the terms of UNCLOS.[65] Some atmospheric methane removal approaches might similarly be found to involve pollution. For example, if AOE were performed by releasing iron particles from vessels or aircraft over the ocean, some of the particles would end up landing on the surface of the water, where they could stimulate phytoplankton blooms that lead to macronutrient diversion from other parts of the ocean and thus harm fishing or other marine life.

Legal scholars have argued that certain CDR projects might also be sources of marine pollution (Burns, 2023; Reynolds, 2016; Webb, 2023). Some have, however, countered that CDR projects should be viewed as a form of pollution control (i.e., because they are designed to remove CO_2 from the upper ocean and thus combat the effects of CO_2 emissions, which ITLOS has identified as a source of marine pollution) (Reynolds, 2018). ITLOS did not address this in detail in the May 2024 advisory opinion, but it did note that "Article 195 of [UNCLOS] requires States, in taking measures to prevent, reduce and control pollution of the marine environment, not to transfer . . . damage or hazards from one area to another or transform one type of pollution into another."[66] ITLOS then stated, "Marine geoengineering would be contrary to article 195 if it has the consequence of transforming one type of pollution into another."[67] In the future, countries may look to atmospheric methane removal as a means of combating marine pollution from greenhouse gas emissions and thus meet their UNCLOS obligations. However, as indicated by ITLOS, countries would need to ensure that the activities they undertake do not cause further pollution of the marine environment. Additional research is needed on this and other issues relating to the application of UNCLOS to atmospheric methane removal activities.

3.2.3.2 Conservation and Sustainable Use of Marine Biological Diversity beyond National Jurisdiction Treaty

In June 2023, the parties to UNCLOS adopted, by consensus, the Conservation and Sustainable Use of Marine Biological Diversity beyond National Jurisdiction (BBNJ) treaty.[68] That treaty opened for signature on September 20, 2023, but had not yet entered into force at the time of writing (UN, 2023a).

The BBNJ treaty establishes a framework for countries to use area-based management tools (ABMTs), including marine protected areas, for conserving and restoring biodiversity in the high seas or seabed beyond national jurisdiction.[69] In the future, ABMTs could be used to direct atmospheric methane removal activities away from certain high seas areas (e.g., with high

---

[64] ITLOS Advisory Opinion on Climate Change at para. 161.
[65] ITLOS Advisory Opinion on Climate Change at para. 179.
[66] ITLOS Advisory Opinion on Climate Change at para. 231.
[67] ITLOS Advisory Opinion on Climate Change at para. 231.
[68] Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity in Areas beyond National Jurisdiction, A/CONF.232/2023/4*, June 19, 2023 (hereinafter BBNJ Agreement).
[69] BBNJ Agreement, Art. 17–26.

biodiversity) and/or otherwise control how they take place. The BBNJ treaty also includes provisions requiring EIAs for certain activities taking place on, or impacting, the high seas and/or the underlying seabed, which could have implications for atmospheric methane removal projects.[70] Scholars have begun to explore how these provisions of the BBNJ treaty might apply to other NETs (particularly ocean-based CDR approaches), but, to date, there has been no detailed examination of their application to atmospheric methane removal (see, e.g., Burns and Webb, 2023).

3.2.3.3 London Convention and Protocol

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) was adopted in November 1972 and entered into force in August 1975. The London Convention aims to "promote the effective control of all sources of pollution of the marine environment," particularly those resulting from the "dumping" of "waste or other matter" at sea.[71] In November 1996, the parties to the London Convention adopted a new protocol, which sets more ambitious goals than the London Convention, aiming to "protect and preserve the marine environment from all sources of pollution" and to "prevent, reduce and where practicable eliminate pollution caused by dumping" of "waste or other matter."[72]

At the time of writing, there were 87 parties to the London Convention and 53 parties to the London Protocol (EPA, 2023a). For countries that are parties to both instruments, the London Protocol supersedes the London Convention. The United States has only ratified the London Convention and is, therefore, bound only by its terms (EPA, 2023a).

Both the London Convention and Protocol require parties to adopt domestic laws to regulate the dumping of waste and other matter within offshore areas under their jurisdiction (i.e., the territorial sea and EEZ) and, outside of those areas, by vessels or aircraft that are registered or were loaded within their territory.[73] In both instruments, "waste or other matter" is defined to mean "material of any kind, form or description."[74] "Dumping" is defined to mean the "deliberate disposal of waste or other matter at sea from vessels, aircraft, platforms, or other man-made structures," but there is an exemption for the "placement of matter for a purpose other than mere disposal thereof, provided that such placement is not contrary to the aims of" the London Convention or Protocol (the "dumping exemption").[75]

Notably, the London Convention and Protocol include specific provisions governing dumping through "incineration at sea," which is defined as the combustion of waste or other matter for the purposes of thermal destruction.[76] This could have implications for AOE projects

---

[70] BBNJ Agreement, Art. 27–39.
[71] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Art. I–II, Dec. 29, 1972 (hereinafter London Convention).
[72] Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, Art. 2, Nov. 7, 1996 (hereinafter London Protocol).
[73] London Convention, Art. VII; London Protocol, Art. 10.
[74] London Convention, Art. III; London Protocol, Art. 1.
[75] London Convention, Art. III; London Protocol, Art. 1.
[76] London Convention, Annex I; London Protocol, Art. 1 & 6.

in which aircraft or vessels are used to disperse materials over ocean areas. This is because the materials would be released via the aircraft or vessel exhaust, as a result of the combustion of specially formulated fuels, which could be viewed as involving the thermal destruction of matter. However, the purpose of combustion would not be thermal destruction of matter but rather the production of reactive species to react with methane. Further legal analysis may be needed to determine whether this distinction in intent is relevant under the London Convention and Protocol.

AOE might also result in ocean fertilization, which the parties to the London Convention and Protocol have taken steps to control through a series of nonbinding resolutions. Since the resolutions are nonbinding, parties are not legally required to comply with them. However, some argue that the resolutions must be consulted in the context of interpreting the provisions of the two agreements (Proelss, 2021).

In 2008, the parties to the London Convention and Protocol adopted a resolution defining when ocean fertilization will constitute dumping.[77] The 2008 resolution defined "ocean fertilization" to mean "any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans" (with the exception of conventional aquaculture and mariculture).[78] When the resolution was adopted, the concern was about ocean fertilization projects that add iron or other nutrients directly to ocean water. However, in theory, the resolution could also apply to atmospheric methane removal projects that lead to ocean fertilization. Atmospheric methane removal project proponents may argue that their principal intention is to destroy methane (not to stimulate primary production in the ocean), but opponents may argue that aerosolizing iron is an attempted circumvention of the iron fertilization decisions, especially if those projects are selling carbon credits associated with ocean fertilization.

The 2008 resolution draws a distinction between ocean fertilization research and deployment. According to the resolution, ocean fertilization activities conducted as part of "legitimate scientific research . . . should be regarded as placement of matter for a purpose other than mere disposal" and thus will qualify for the dumping exemption if they are not contrary to the aims of the London Convention or Protocol.[79] A framework for assessing research projects was adopted in 2010.[80] It provides for a two-stage review of projects by the country under whose jurisdiction they occur. The relevant country must first conduct an "initial assessment" to determine whether the project "has proper scientific attributes" to qualify as "legitimate scientific research."[81] Projects that qualify must then undergo an environmental assessment.[82] A project may only be approved if "conditions are in place that ensure that, as far as practicable,

---

[77] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization (Oct. 31, 2008) (hereinafter 2008 Resolution).

[78] 2008 Resolution, Art. 2.

[79] 2008 Resolution, Art 3.

[80] Resolution LC-LP.2(2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization (Oct. 14, 2010) (hereinafter 2010 Resolution).

[81] 2010 Resolution, Annex I, cl. 1.3.1.

[82] 2010 Resolution, Annex I, cl. 3.

environmental disturbance and detriment would be minimized and the scientific benefits maximized."[83]

Whereas the 2008 resolution and 2010 assessment framework envisage that some ocean fertilization research may qualify for the dumping exemption, deployment has been viewed differently. The 2008 resolution declares that "ocean fertilization activities other than legitimate scientific research" are contrary to the aims of the London Convention and Protocol and thus do not qualify for the dumping exemption.[84]

In 2013, the parties to the London Protocol agreed to an amendment that intended to establish a new permitting regime for activities involving the "placement of matter into the sea" for the purposes of "marine geoengineering."[85] The amendment defines marine geoengineering to mean 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."[86] It requires parties to the London Protocol to prohibit the "placement of matter into the sea" for "marine geoengineering activities listed in annex 4, unless the listing provides that the activity . . . may be authorized under a permit."[87] To date, only ocean fertilization has been listed, but several other CDR and solar radiation management (SRM) activities are currently being considered for listing.[88] Atmospheric methane removal activities that involve the placement of matter in the sea could similarly be listed in the future.

It should be noted that the 2013 amendment has not yet entered into force and thus is not legally binding. However, a legal committee appointed to advise the London Convention and Protocol parties on marine geoengineering has urged parties to "refrain from acts which would defeat the object and purpose of the amendment," and suggested that it could be provisionally applied before it enters into force.[89]

In October 2023, the parties to the London Convention and Protocol issued a Statement on Marine Geoengineering in which they declared that certain ocean CDR and SRM activities[90] have "the potential for deleterious effects that are widespread, long-lasting or severe," and thus

---

[83] 2010 Resolution, Annex I, cl. 4.4.
[84] 2008 Resolution, Art. 8.
[85] Resolution LP .4(8), Amendment to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 to Regulate Marine Geoengineering (Oct. 18, 2013) (hereinafter 2013 Amendment).
[86] 2013 Amendment, Annex 1, Art. 1.
[87] 2013 Amendment, Annex 1, Art. 1.
[88] 45th Consultative Meeting of Contracting Parties to the London Convention and the 18th Meeting of Contracting Parties to the London Protocol (LC 45/LP 18), Statement on Marine Geoengineering 2023.
[89] Progress report form the Legal Intersessional Correspondence Group on Marine Geoengineering, IMO Doc. LC 45/4/1 (June 30, 2023); Draft background paper on provisional application of the 2013 LP amendment (resolution LP.4(8)) from the Legal Intersessional Correspondence Group on Marine Geoengineering, IMO Doc. LC 45/5/4 (July 28, 2023).
[90] The parties looked specifically at ocean alkalinity enhancement, biomass cultivation for carbon removal, marine cloud brightening, and surface albedo enhancement involving reflective particles and/or other materials.

"[a]ctivities other than legitimate scientific research should be deferred."[91] The statement also endorsed the 2010 assessment framework, stating that it should "form the appropriate basis for the assessment of proposed research and development projects relating to marine geoengineering."[92] The parties might be expected to take a similar approach to atmospheric methane removal activities.

3.2.4 Montreal Protocol

Some proposed atmospheric methane removal techniques, like AOE, have the potential to affect the ozone layer. Although research has not yet confirmed this potential impact, complex, nonlinear alterations to atmospheric chemistry from aerosol dispersal for the purpose of AOE could bring ozone layer depletion risks. If research confirms AOE's potential to impact the ozone layer, use of the techniques could implicate the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol).

The Montreal Protocol was adopted in September 1987 and entered into force in January 1989 (UN, n.d.-a). The agreement has universal global participation with 197 signatories (UN, n.d.-a). The parties to the Montreal Protocol have agreed to "protect the ozone layer by taking precautionary measures to control equitably total global emissions of substances that deplete it."[93] This is achieved by phasing out the production and consumption of ozone-depleting substances. Controlled substances are listed in the annex to the Montreal Protocol, and parties have flexibility to expand the list over time.

The parties to the Montreal Protocol have adopted a decision to assess the potential of SRM and its effect on the atmosphere.[94] That decision directed expert panels on science, environmental effects, and technology and economy to conduct the assessment. This resulted in the inclusion of a chapter on SRM in the *Scientific Assessment of Ozone Depletion 2022*, which concluded, among other things, that SRM through stratospheric aerosol injection has the potential to reduce global mean temperatures, that SRM cannot fully offset the effects of global warming and produces unintended consequences, that SRM could cause additional ozone depletion, and that different aerosols might have differing effects on the ozone layer (WMO, 2022). In 2023, the parties to the Montreal Protocol issued a draft decision that "[i]nvites the global scientific community to address risks and uncertainties for the ozone layer in any scientific studies or assessments undertaken in relation to stratospheric aerosol injection."[95] If

---

[91] 45th Consultative Meeting of Contracting Parties to the London Convention and the 18th Meeting of Contracting Parties to the London Protocol (LC 45/LP 18), Statement on Marine Geoengineering 2023, https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/LC-45-LP-18.aspx

[92] 45th Consultative Meeting of Contracting Parties to the London Convention and the 18th Meeting of Contracting Parties to the London Protocol (LC 45/LP 18), Statement on Marine Geoengineering 2023, https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/LC-45-LP-18.aspx

[93] Preamble, Montreal Protocol on Substances that Deplete the Ozone Lawyer, September 16, 1987.

[94] Decisions adopted by the Thirty-First Meeting of the Parties to the Montreal Protocol, Decision XXXI/2 5(g), Nov. 11, 2019, https://ozone.unep.org/system/files/documents/MOP-31-9-Add-1E.pdf

[95] Draft decisions for consideration by the Thirty-Fifth Meeting of the Parties to the Montreal Protocol, Draft decision XXXV/B, July 19, 2023, https://ozone.unep.org/system/files/documents/MOP-35-3E.pdf

AOE or other atmospheric methane removal approaches demonstrate potential to damage the ozone layer, the Montreal Protocol expert panels might similarly be engaged to assess this potential. This could form the first step toward potential regulation of the production and use of the substances used in AOE.

3.2.5 Convention on Long-Range Transboundary Air Pollution (LRTAP)

LRTAP, signed in 1979 and entered into force in 1983, aims to reduce transboundary air pollution. The convention has 51 parties, mostly in North America and Europe, including the United States. LRTAP is notable both for its success in reducing emissions of harmful substances and air pollution and for its success in building an extensive network of scientists who exchange information with policymakers to develop innovative emission control approaches (UNECE, n.d.).

Parties could utilize LRTAP to regulate or incentivize atmospheric methane removal activities in two ways. Parties could (1) incentivize atmospheric methane removal as a way to control transboundary air pollution from methane emissions or (2) regulate atmospheric methane removal activities directly as potential sources of transboundary air pollution. LRTAP parties have adopted eight protocols, most of which address specific pollutants (U.S. Department of State, n.d.-b). The United States is a party to four of these protocols, including the Gothenburg Protocol, which seeks to reduce acid rain and ground-level ozone by targeting emissions of sulfur dioxide, nitrogen oxides, volatile organic compounds, particulate matter (PM), and black carbon.[96] The Gothenburg Protocol sets targeted emissions reduction levels for certain sources, like electric generating units, boilers, and vehicles.[97]

LRTAP does not currently address methane emissions directly in its protocols. Parties have, however, identified methane emissions as an issue of importance and have noted that the Gothenburg Protocol should consider appropriate steps toward reducing methane emissions as a way to control ground-level ozone (Mar et al., 2022). If the parties do address methane emissions through the Gothenburg Protocol, atmospheric methane removal could be utilized as a control tool to reduce pollution resulting from methane emissions.

LRTAP could also be used to regulate atmospheric methane removal activities such as AOE or surface treatments. Those activities are not, at the time of writing, listed as sources of air pollution under the Gothenburg Protocol. In the future, those activities could be viewed as a

---

[96] 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone to the Convention on Long-range Transboundary Air Pollution, May 5, 2005; Decision 2012/1 Amendment of annex I to the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone; Decision 2012/2 Amendment of the text of and annexes II to IX to the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and the addition of new annexes X and XI.

[97] 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone to the Convention on Long-range Transboundary Air Pollution, May 5, 2005; Decision 2012/1 Amendment of annex I to the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone; Decision 2012/2 Amendment of the text of and annexes II to IX to the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and the addition of new annexes X and XI.

source of transboundary air pollution and regulated through the LRTAP protocols based on, for example, the concern that atmospheric methane removal activities could inadvertently increase ground-level ozone. LRTAP's extensive scientific network could drive research to develop appropriate regulation of atmospheric methane removal use.

3.2.6 Environmental Modification Convention

The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) was adopted in December 1976 and entered into force in October 1978. At the time of writing, there were 78 parties to ENMOD, including the United States. Parties to ENMOD agree "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects."[98] ENMOD defines "environmental modification techniques" as those intended to change, "through the deliberate manipulation of natural processes, the dynamics, composition or structure of the Earth."[99] This definition would likely include atmospheric methane removal projects, but ENMOD would only prohibit such projects if they were undertaken for hostile purposes. ENMOD would not apply to atmospheric methane removal projects undertaken for peaceful purposes, including to mitigate climate change.

3.2.7 The Arctic Council

The Arctic region may be well suited to atmospheric methane removal research into, for example, methane uptake capacity in Arctic soils (Voigt et al., 2023). Atmospheric methane removal research activities in the region may implicate the governance of the Arctic Council and its associated legally binding agreements. The Arctic Council, established in 1996, is a non-treaty based international forum that is made up of eight Arctic states and Indigenous groups of the Arctic.[100] The Council has adopted three legally binding agreements, including the 2017 Agreement on Enhancing International Arctic Scientific Cooperation.[101] The Agreement aims to facilitate access to research areas, access to research infrastructure and facilities, access to data collected during experiments, and entry and exit of researchers into the region to conduct scientific activities.[102] Notably, the Agreement defines scientific activities as "efforts to advance understanding of the Arctic."[103] As such, atmospheric methane removal research projects that seek to take advantage of the benefits of the Agreement may need to gear their research toward advancing Arctic understanding in some way—for example, through better understanding natural methane emissions in Arctic regions—in addition to advancing understanding of atmospheric methane removal.

---

[98] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Art. I, May 18, 1977 (hereinafter ENMOD).
[99] ENMOD, Art. II.
[100] Arctic Council, Declaration on the Establishment of the Arctic Council, September 19, 1996.
[101] Arctic Council, Agreement on Enhancing International Arctic Scientific Cooperation, May 11, 2017.
[102] Arctic Council, Agreement on Enhancing International Arctic Scientific Cooperation, May 11, 2017.
[103] Arctic Council, Agreement on Enhancing International Arctic Scientific Cooperation, May 11, 2017.

3.3 State Responsibility for Violations of International Law

Broadly, the law of state responsibility defines when a country may be held responsible for a breach of its international commitments, and the consequences and remedies that flow from such breach. As articulated in the 2001 United Nations Resolution on the Responsibility of States for Internationally Wrongful Acts, state responsibility is incurred when one country commits an "intentionally wrongful act," which the Resolution defines as occurring when a country engages in "conduct consisting of an action or omission" that is "attributable to the [country] under international law" and "[c]onstitutes a breach of an international obligation" of the country.[104] Articles 12 and 13 of the Resolution clarify that a country breaches an international obligation when it acts in a way that "is not in conformity with what is required of it" under an international obligation by which it is bound.[105] Under Article 30 of the Resolution, where such a breach occurs, the country must cease the offending conduct and "offer appropriate assurances and guarantees of non-repetition."[106] The country must also make "full reparation" for any injuries caused by its conduct through restitution (i.e., action to re-establish the status quo ante), compensation (i.e., payments to cover any "financially assessable damage"), or satisfaction (i.e., "an acknowledgement of the breach, an expression of regret, a formal apology," or similar statement).[107]

4. DOMESTIC U.S. LAW RELEVANT TO ATMOSPHERIC METHANE REMOVAL

This section explores the applicability of domestic U.S. law to the development and deployment of atmospheric methane removal approaches. Building on the discussion in Section 2 above, this section explains how the applicable legal requirements might differ depending on the atmospheric methane removal approach involved—in particular, whether it uses open or closed systems.

Section 4.1 analyzes crosscutting laws that are likely to apply to all atmospheric methane removal approaches (regardless of whether they involve open or closed systems). These include, among other things, domestic laws establishing requirements for ex-ante review of, and consultation on, projects that may impact the environment (e.g., the National Environmental Policy Act [NEPA] and state "little NEPA statutes"). Since application of these requirements is tied to project impacts, laws like NEPA could, at least in theory, apply to both open and closed system approaches. Moreover, since both types of approaches may require the use of land, Section 4.1 also explores legal issues relating to land access.

---

[104] Resolution Adopted by the United Nations General Assembly, Responsibility of States for Internationally Wrongful Acts, Art. 2, A/RES/56/83 (Jan. 28, 2002) (hereinafter UN Resolution on Responsibility of States).
[105] UN Resolution on Responsibility of States, Art. 12–13.
[106] UN Resolution on Responsibility of States, Art. 30.
[107] UN Resolution on Responsibility of States, Art. 31 & 34.

Section 4.2 analyzes laws relevant to the three atmospheric methane removal approaches involving open systems (i.e., AOE, ecosystem uptake enhancement, and surface treatments). Not all of the laws listed in Section 4.2 will apply to all three approaches. For instance, agricultural laws will be relevant to ecosystem uptake enhancement but not AOE. Section 4.3 focuses on laws applicable to atmospheric methane removal approaches involving closed systems (i.e., methane reactors and methane concentrators). Finally, Section 4.4 discusses liability considerations under domestic law.

4.1 Crosscutting Considerations

4.1.1 Environmental Review

Atmospheric methane removal projects undertaken in the United States may be subject to ex-ante environmental review. NEPA requires federal agencies to prepare an environmental impact statement (EIS) for any major federal action "significantly affecting the quality of the human environment."[108] The requirement applies whether the agency proposes to take the action itself or authorize or fund the action.[109] Thus, for example, NEPA would apply where a federal agency leases land for use in atmospheric methane removal projects or authorizes such projects via the issuance of permits. Federal agencies would need to undertake a case-by-case assessment to determine whether an action is likely to significantly affect the quality of the human environment and thus requires preparation of an EIS. In some cases, a federal agency may know at the outset that a project is likely to have significant effects and proceed directly to prepare an EIS. However, if the effects of a project are unknown or uncertain, the agency may begin with a more limited environmental assessment.[110] If the agency concludes, based on the environmental assessment, that a full EIS is not required, it may issue a finding of no significant impact (FONSI).[111] Conversely, if the environmental assessment shows that a project may have significant impacts, the agency must then prepare a full EIS.[112]

Given the early stage of development of atmospheric methane removal techniques and the significant uncertainties regarding their risks and benefits, many atmospheric methane removal projects are likely to require an environmental assessment. In some cases, those environmental assessments may result in issuance of a FONSI, but, in other cases, they may reveal that a full EIS is required. Large projects, particularly those in sensitive environments, will almost invariably require preparation of an EIS. The EIS would need to assess the natural, economic, social, and cultural resource effects of the installation, and the relevant federal agency would be required to release relevant documents to the public and consider their input.[113]

---

[108] 42 U.S.C. § 4332(2)(C).
[109] 40 C.F.R. § 1508.18(a).
[110] 40 C.F.R. § 1501.5.
[111] 40 C.F.R. § 1501.6
[112] 40 C.F.R. § 1501.3.
[113] 42 U.S.C. 4332(2)(C).

Several states and local governments have enacted their own environmental review laws, sometimes referred to as "little NEPAs," that require an assessment of the environmental impacts of activities permitted at the state or local level (Council on Environmental Quality, n.d.). Many little NEPAs establish similar procedural requirements as the federal NEPA does but impose those requirements on state or local agencies rather than federal agencies. To avoid duplication, many of the little NEPAs provide that if a federal agency prepares an EIS for an activity pursuant to the federal NEPA, no additional state or local EIS is required.[114] But project proponents would still need to ensure that their atmospheric methane removal projects comply with state and local environmental review requirements.

In recent years, NEPA and state and local equivalents have often been criticized on the grounds that compliance with them adds significant time, cost, and complexity to the project approval process. However, ex-ante review of projects serves an important purpose, helping to elucidate environmental risks and possible options for preventing, mitigating, and managing those risks. Steps can be, and recently have been, taken to simplify and streamline the environmental review process. Most notably, the Fiscal Responsibility Act enacted by Congress in 2023 included various amendments to NEPA that, among other things, narrow the scope of major federal actions subject to the Act and impose a 2-year and 150-page limit on EISs (subject to certain exceptions).[115] The White House Council on Environmental Quality (CEQ) finalized a rule updating NEPA implementing regulations on May 1, 2024.[116] Among other things, the rule sets deadlines for agencies to complete environmental reviews; sets specific expectations for lead and cooperating agencies; and allows agencies more flexibility to establish categorical exclusions, which allow agencies to exclude certain projects with similar characteristics from both environmental assessment and EIS requirements.[117]

CEQ and individual federal agencies responsible for implementing NEPA have also taken steps to improve the environmental review process. For example, CEQ has encouraged agencies to make use of programmatic EISs, which assess the environmental impacts of a class of activities or multiple related projects in a single document.[118] Once a programmatic EIS is in place, subsequent project-specific EISs can tier to, or incorporate analysis from, the programmatic EIS.[119] If an individual project does not raise additional issues, beyond those addressed in the programmatic EIS, it may not require a separate EIS. Other studies have discussed how programmatic EISs could be used to streamline the environmental review process for projects involving research or deployment of NETs (e.g., Hester, 2018b; Silverman-Roati, 2022a).

---

[114] See, for example, Cal. Code Regs. tit 14 § 15221.
[115] Fiscal Responsibility Act of 2023, H.R. 3746, 118th Congress (2023).
[116] National Environmental Policy Act Implementing Regulations Revisions Phase 2, 40 C.F.R. pts 1500–08.
[117] National Environmental Policy Act Implementing Regulations Revisions Phase 2, 40 C.F.R. pts 1500–08.
[118] 40 C.F.R. §§ 1501.11 & 1502.4; Final Guidance for Effective Use of Programmatic NEPA Reviews, 79 Fed. Reg. 76986 (Dec. 23, 2014).
[119] 40 C.F.R. § 1501.11.

4.1.2 Species Protection

Before approving, rejecting, or funding atmospheric methane removal projects, federal agencies may also be required to consult with the Fish and Wildlife Service (FWS) and/or the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). Under Section 7 of the ESA, before undertaking, funding, or authorizing any action that may affect listed threatened or endangered species, federal agencies must consult with FWS (for terrestrial and freshwater species) and NMFS (for marine species).[120] Actions that are found to "jeopardize the continued existence of" threatened or endangered species or "result in the destruction or adverse modification of" their critical habitat cannot go ahead unless modified to avoid such adverse effects.[121]

While the above requirement only applies to actions that are undertaken, authorized, or funded by a federal agency, the ESA also imposes requirements on purely private activities. Most notably, Section 9 of the ESA makes it unlawful for any person to kill, harm, or otherwise "take" an endangered species.[122] Under Section 10 of the ESA, FWS and NMFS may issue incidental take permits, authorizing the take of endangered species where it is incidental to and not the purpose of an otherwise lawful activity.[123] Applications for incidental take permits must include a habitat conservation plan that explains the likely impact of the taking, "what steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps."[124]

Other species protection laws also impose consultation and other requirements that atmospheric methane removal researchers and project developers will need to be aware of. For example, pursuant to the Migratory Bird Treaty Act (MBTA), federal agencies must consult with FWS to ensure that activities they undertake or authorize do not harm seabirds protected under that Act.[125] Additionally, where an action could harm "essential fish habitat" designated under the Magnuson-Stevens Fishery Conservation and Management Act, federal agencies must consult with NMFS.[126]

4.1.3 Land Acquisition and Use

Atmospheric methane removal systems not deployed in the ocean will require the use of land, which will need to be legally authorized. The approach to, and difficulty associated with, securing the necessary authorizations will depend partly on the land use requirements, which will differ between atmospheric methane removal approaches. For instance, ecosystem uptake enhancement and surface treatments may require significantly more land use than methane

---

[120] 16 U.S.C. §§ 1352(5), 1536(a)(2).
[121] 16 U.S.C. §§ 1352(5), 1536(a)(2). See also Tennessee Valley Auth. v Hill [1978] 437 US 153, 173 & 184–185.
[122] 16 U.S.C. § 1538.
[123] 16 U.S.C. § 1539(a)(1).
[124] 16 U.S.C. § 1539(a)(2).
[125] 16 U.S.C. § 703(a).
[126] 16 U.S.C. § 1855(b)(2).

reactors or methane concentrators to achieve the same level of methane removal. But even approaches that have low direct land use requirements may require large tracts of land for associated energy facilities (e.g., solar farms to power methane reactors).

In the United States, project proponents have the option of fee simple, leasehold, or other types of access authorizations to use land, with varying associated costs and requirements. Accessing land to pursue atmospheric methane removal projects should be relatively straightforward from a legal perspective where the landowner is willing to sell, lease, or otherwise allow the projects to go forward. However, once the land is bought or leased, projects will still need to comply with any federal, tribal, state, or local limitations on the use of the land. As a general rule, the greater the land use requirements, the greater the likelihood of legal complications. Greater land use requirements are more likely to affect endangered species habitat and to impact alternative land users, implicating the environmental review and species protection requirements discussed above (among other things).

There may be interest in developing atmospheric methane removal projects on federal land. The federal government owns approximately 28% of the total land area of the United States, equivalent to roughly 640 million acres (Vincent et al., 2020). Nearly 40% of this land—approximately 245 million acres—is managed by the U.S. Department of the Interior's Bureau of Land Management (BLM) (Vincent et al., 2020). BLM's management of the land is governed by the principle of "multiple use," which requires the land and its resources to be "utilized in the combination that will best meet the present and future needs of the American people" while avoiding "permanent impairment of the productivity of the land and the quality of the environment."[127] BLM must also adhere to the principle of "sustained yield," ensuring the maintenance of "high-level . . . output of the various renewable resources" within the land.[128] Where consistent with those principles, BLM may authorize third parties to use public lands.

Atmospheric methane removal projects on federal lands will generally need to be authorized by BLM under the Federal Land Policy and Management Act (FLPMA).[129] BLM may authorize land use in a number of different ways, including via

- permits, which are issued for short-term land uses (not exceeding 3 years) that involve little or no land improvement, construction, or investment;
- leases, which are issued for longer-term land uses that involve substantial construction or land improvement, and the investment of large amounts of capital; and
- easements, which are issued for land uses that are compatible with other uses, occurring on nearby or adjacent land.[130]

---

[127] 43 U.S.C. §§ 1702(c) & 1732(a).
[128] 43 U.S.C. §§ 1702(h) & 1732(a).
[129] 43 U.S.C. § 1701 et seq.
[130] 43 C.F.R. § 2920.1-1.

All approved uses of public land must be consistent with resource management plans (RMPs), which are issued by BLM to guide its land management decisions.[131] BLM takes the view that for an activity to be consistent with the applicable RMP, it must occur in an area identified as suitable for that type of activity.[132] As no RMPs deal with atmospheric methane removal projects, the applicable RMP for a given area would need to be amended before a project could be developed in that area. BLM has indicated previously that it will consider RMP amendments for geologic carbon sequestration on a case-by-case basis (U.S. Department of the Interior, 2009, p.10). The agency might be expected to take a similar approach to atmospheric methane removal projects.

It should be noted that access to land, including federal land, is also an issue for CDR projects. Previous studies have highlighted various challenges CDR developers might face in obtaining necessary land use authorizations and suggested legal reforms and other actions to lessen those challenges (Eisenson and Webb, 2023; Hester, 2018b; Webb, 2020). These include, among other recommendations, early engagement with relevant government officials (including at the local level) and other stakeholders, and negotiation of community benefit agreements to ensure that local residents can share in the benefits arising from projects (Eisenson and Webb, 2023). The suggested actions should also be considered in the context of atmospheric methane removal activities.

4.2 Domestic Law Relevant to Open Systems

This subsection analyzes domestic laws that are relevant to open system atmospheric methane removal approaches. Open systems might have a range of environmental impacts and thus trigger the application of domestic environmental laws designed to, for example, protect against pollution of the air and ocean. The crosscutting considerations discussed above (in Section 4.1) are also relevant to open systems, so the issues discussed in this subsection are additional to those considered above.

4.2.1 Agriculture Laws

Some atmospheric methane removal projects may be interested in utilizing agricultural lands, especially where projects aim to increase atmospheric methane removal in soils. Several states and localities across the United States have "agricultural preservation laws" aimed at ensuring the availability of land for agricultural use. In general, through these laws, state governments authorize municipal governments to adopt zoning ordinances to preserve agricultural land and restrict nonagricultural activities in preserved land. For example, Pennsylvania state law authorizes municipalities to adopt "provisions to promote and preserve prime agricultural land."[133] Pursuant to that authority, several municipalities in the state have

---

[131] 43 U.S.C. §§ 1712 & 1732.
[132] 43 C.F.R. § 1610.
[133] 53 PA. Cons. Stat. § 10603(b)(7).

established agricultural protection zones in which only agricultural activities are permitted by right, and other uses require special approval (Pennsylvania Land Trust Association et al., 2013). Ecosystem uptake enhancement projects, especially those that may be deployed in tandem with agricultural systems like nutrient amendments, would need to be analyzed on a case-by-case basis to determine whether they comply with these ordinances. For nutrient amendment projects on agricultural lands, project proponents could likely argue that the practice is akin to traditional agricultural practices like fertilizer addition. Furthermore, the practice is unlikely to transform land from agricultural use, which is what the zoning ordinances are intended to prevent.

Those wishing to undertake atmospheric methane removal projects on agricultural lands should also be aware of laws restricting the substances that can be applied to such land. For example, Environmental Protection Agency (EPA) regulations prohibit the application of "bulk sewage sludge" to agricultural land unless certain requirements are met (e.g., to ensure that cumulative pollutant loading rates are not exceeded).[134] Some states impose additional restrictions on the application of sewage sludge and other materials to agricultural lands.

Atmospheric methane removal projects on agricultural lands may also implicate permitting requirements under the Clean Water Act (CWA). The CWA aims to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[135] To that end, the CWA prohibits "the discharge of any pollutant by any person" without a permit issued under the National Pollutant Discharge Elimination System.[136] For the purposes of the CWA, a "discharge" occurs where a pollutant is added to waters of the United States from a "point source," meaning a "discernible, confined and discrete conveyance."[137] The term "pollutant" is defined broadly in the CWA to mean "dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water."[138] Both sewage and agricultural waste are notable here, as atmospheric methane removal in soils could involve the addition of sewage to agricultural lands and subsequent runoff of that sewage or agricultural waste, containing copper or other pollutants, into nearby waters.

It should be noted that the CWA permitting requirements only apply to discharges into "waters of the United States." The meaning of that phrase has been litigated heavily in recent years. In a 2023 decision, the Supreme Court held that the phrase only encompasses "those relatively permanent, standing or continuously flowing bodies of water forming geographical features that are described in ordinary parlance as 'streams, oceans, rivers, and lakes'" (internal citations omitted).[139] The Supreme Court further held that wetlands will also qualify but only if they have "a continuous surface connection to bodies that are waters of the United States in their

---

[134] 40 C.F.R. § 503.12.
[135] 33 U.S.C. § 1251.
[136] 33 U.S.C. § 1311.
[137] 33 U.S.C. § 1362.
[138] 33 U.S.C. § 1362.
[139] Sackett v. Environmental Protection Agency, 598 U.S. ___ (2023).

own right."[140] Thus, whether the CWA permitting requirements apply to an atmospheric methane removal project resulting in the discharge of pollutants into water bodies will depend on the nature of the receiving bodies and whether they qualify as "waters of the United States" under the CWA.

Atmospheric methane removal project proponents should also be cognizant of exceptions to the CWA permitting requirements that are available for agricultural runoff. The CWA definition of "point source" excludes directed runoff that is comprised entirely of "return flows from irrigated agriculture." While the CWA does not define what constitutes agricultural "return flows," EPA has previously interpreted that term to mean "surface water . . . containing pollutants which result from the controlled application of water by any person to land used primarily for crops, forage growth, or nursery operations" (Webb, 2020, p. 32). This could cover atmospheric methane removal projects that are conducted on irrigated croplands and only discharge pollutants into waterways through runoff resulting from irrigation. Those projects are, therefore, unlikely to trigger CWA permitting requirements. An analysis of the CWA's application to the CDR approach of enhanced weathering on agricultural lands came to a similar conclusion (Webb, 2020, p. 32).

4.2.2 Clean Air Laws

Some atmospheric methane removal approaches, such as AOE, may involve the dispersal of materials into the atmosphere. This could implicate domestic air pollution laws. In the United States, air pollution is regulated under the federal Clean Air Act (CAA), which adopts a "cooperative federalism" approach in which regulatory authority is shared among federal, state, and, in some cases, local bodies. At the federal level, EPA is required to identify "criteria air pollutants," which are emitted by numerous mobile or stationary sources and cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare.[141]

For each criteria pollutant, EPA must establish National Ambient Air Quality Standards (NAAQS), reflecting the maximum safe concentration of the pollutant in air.[142] The NAAQS are enforced via State Implementation Plans (SIPs) that are prepared by states and approved by EPA. In some areas where SIPs have not been adopted, EPA prepares and enforces Federal Implementation Plans. EPA also develops standards for facilities emitting air pollutants that have not been listed as criteria pollutants but, in the judgment of the administrator, "cause[] or contribute[] significantly to[] air pollution which may reasonably be anticipated to endanger public health or welfare."[143] Implementation and enforcement of those standards is, again, shared among federal and state bodies.

Atmospheric methane removal projects that result in the release of substances into the air may be regulated under the CAA. Each project would need to be evaluated on a case-by-case

---

[140] Sackett v. Environmental Protection Agency, 598 U.S. ___ (2023).
[141] 42 U.S.C. § 7408.
[142] 42 U.S.C. § 7409.
[143] 42 U.S.C. § 7411.

basis, taking into account the specific activities involved, the location of those activities, and the nature and amount of any substance released. Taking AOE as an example, it would be important to consider (among other things) the method by which materials would be dispersed into the atmosphere. In some projects, iron-based particles might be dispersed from fixed structures, which could qualify as "stationary sources" of air pollution under the CAA. Other projects might involve the use of "mobile sources," for example, where fuel with iron additives is used in aircraft to increase their iron emissions. The distinction is important because under the CAA, emissions from stationary sources are regulated differently than those from mobile sources.

AOE projects that use fixed structures to release iron particles into the air may, depending on the size of the particles, be regulated as a stationary source of PM pollution under the CAA. EPA has listed two classes of PM as criteria pollutants under the CAA: (1) inhalable particles that are less than 2.5 microns in diameter (PM2.5) and (2) inhalable particles that are less than 10 microns in diameter (PM10) (EPA, n.d.-a). A permit from EPA or an authorized state or local authority is required to construct or modify a "major stationary source" of PM onshore in the United States and in certain offshore locations under U.S. jurisdiction.[144] What constitutes a "major" source depends, in part, on local air quality. In onshore areas that have already attained the NAAQS and adjacent offshore areas, a source is generally considered major if it emits or has the potential to emit 250 tons or more of PM annually.[145] In other areas, facilities with lower annual emissions may be considered major stationary sources and require a permit under the CAA. Some states have established, in their SIPs, additional permitting requirements for facilities that don't qualify as major sources under the CAA.

The above permitting requirements only apply to stationary, and not mobile, sources of air pollution. Different requirements would thus apply to AOE projects that rely on aircraft to emit iron particles into the atmosphere (i.e., via the use of iron-enriched fuel). Responsibility for regulating aircraft emissions is shared between EPA and the Federal Aviation Administration (FAA). Briefly, EPA is required to establish standards governing "the emission of any air pollutant from . . . aircraft engines which in [the administrator's] judgment causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare."[146] Importantly, however, EPA does *not* have authority to regulate aircraft fuel or fuel additives. That authority rests with the FAA, which must adopt "standards for the composition or chemical or physical properties of an aircraft fuel or fuel additive to control or eliminate" emissions of any pollutant that EPA has found endangers public health or welfare.[147] That is, EPA is responsible for establishing aircraft engine emissions standards, while the FAA must regulate aircraft fuel and fuel additives to ensure that those standards are met. EPA has identified PM emissions from aircraft engines as a source of air pollution that endangers public health or welfare and adopted

---

[144] 42 U.S.C. §§ 7475, 7502, 7503, & 7627.
[145] Certain sources emitting 100 tons or more per year in attainment areas are considered major sources under the CAA. See 42 U.S.C. § 7479(1).
[146] 42 U.S.C. § 7571.
[147] 49 U.S.C. § 44714.

standards therefor.[148] As such, if an AOE project involving the use of iron fuel additives were to result in an increase in aircraft PM emissions, the FAA may take steps to regulate the additives to control those emissions.

Prior studies have explored the implications of these and other CAA requirements for certain CDR activities, such as enhanced weathering, as well as SRM (Reynolds, 2019; Webb, 2020). Similar to some atmospheric methane removal approaches, certain CDR and SRM activities might involve the dispersal of materials into the air and thus be regulated as sources of PM pollution under the CAA. Experience with permitting and other regulation of those activities could, therefore, be instructive for atmospheric methane removal.

4.2.3 Ocean Dumping Laws

Some atmospheric methane removal activities conducted in the ocean may be regulated under the MPRSA. Adopted to implement U.S. obligations under the London Convention (discussed above), the MPRSA regulates "the dumping of all types of materials into ocean waters" within 12 nm of the U.S. coast and farther in some circumstances.[149] Dumping is defined broadly in the MPRSA to encompass any "disposition" of "matter of any kind or description."[150] Applying this definition, some atmospheric methane removal activities might involve dumping and thus be regulated under the MPRSA. For example, in AOE, iron salts may be aerosolized over the ocean and end up landing on the surface of the water. This could be viewed as a disposition of material under the MPRSA.

Regulators might view AOE using iron salts as similar to the ocean CDR approach of ocean fertilization. Previous analyses have found that the MPRSA will apply to ocean fertilization projects (provided certain requirements are met) (Silverman-Roati et al., 2022b). It may be possible to distinguish AOE because whereas ocean fertilization involves direct application of iron to ocean waters, the material dispersed in AOE reaches ocean waters indirectly. However, EPA may view even indirect disposition as a regulated act, as the MPRSA has been held to apply to incineration at sea, which similarly results in aerosolized emissions that may land on the surface of the ocean (EPA, n.d.-b).

Where the MPRSA does apply, it may require atmospheric methane removal projects to be permitted by EPA. Under the MPRSA, an EPA permit is required to dump materials in ocean waters when

- the materials to be dumped are transported from within the United States (regardless of where the dumping occurs); or

---

[148] Control of Air Pollution from Aircraft Engines: Emission Standards and Tests Procedures, 87 Fed. Reg. 72312 (Nov. 23, 2023). EPA has also adopted standards to control other emissions from aircraft engines, including greenhouse gases, carbon monoxide, nitrogen oxides, hydrocarbons, smoke exhaust, and fuel venting. See generally 40 C.F.R. Pt. 87, 1030, and 1031.
[149] 33 U.S.C. § 1401.
[150] 33 U.S.C. § 1402.

- the materials are transported from outside the United States and
    - transportation occurs on a vessel registered in the United States (regardless of where the dumping occurs), or
    - the dumping occurs within 12 nm of the U.S. coast (regardless of how the materials are transported).[151]

EPA can issue "research permits" that authorize the dumping of materials into ocean waters "as part of a research project."[152] Research permits may be issued for a maximum of 18 months if EPA determines that "the scientific merit of the proposed [research] project outweighs the potential environmental or other damage that may result from the dumping."[153] Neither the MPRSA nor EPA's implementing regulations include a definition of "research project," resulting in some uncertainty as to what activities qualify for research permits. Some, albeit limited, guidance is provided by past EPA practice. Between 1974 and 1982, EPA issued four research permits for ocean incineration projects to test the efficiencies of the incinerators and evaluate the operating conditions of the vessels used (EPA, 1987). EPA has also issued research permits for the dumping of fish processing wastes to enable an assessment of different processing approaches and their environmental impacts (EPA, 2023b) and, at the time of writing, had announced a tentative decision to issue research permits for ocean alkalinity enhancement research.[154] At least some of the permitted projects were conducted by commercial entities, suggesting that commercial research and development projects may qualify for research permits. However, it remains unclear whether EPA might impose other restrictions—for example, on where or by whom research projects can be conducted. The resulting uncertainty previously has been identified as a potential barrier to advancing ocean CDR research (Webb & Silverman-Roati, 2023) and could, similarly, hinder some atmospheric methane removal research.

EPA can also authorize dumping activities that are unconnected with research through "general" or "special" permits. General permits can be issued for the dumping of materials that "will have minimal adverse environmental impact and are generally disposed of in small quantities."[155] Special permits are used for the dumping of other materials. Before issuing special permits, EPA must consider "the environmental effect of the proposed dumping operation, the need for ocean dumping, alternatives to ocean dumping, and the effect of [dumping] on esthetic, recreational and economic values and on other uses of the oceans."[156] EPA can only issue a permit if satisfied that dumping "will not unreasonably degrade or endanger human health,

---

[151] 33 U.S.C. § 1411.
[152] 40 C.F.R. § 220.3(e).
[153] 40 C.F.R. § 220.3(e)
[154] EPA, Notice of Permit Applications and Tentative Determinations, EPA-HQ-MPRSA-2024-001 and EPA-HQ-MPRSA-2024-002, https://www.epa.gov/system/files/documents/2024-05/whoi-loc-ness-public-notice.pdf
[155] 40 C.F.R. § 220.3(a).
[156] 40 C.F.R. § 227.1.

welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[157]

As with the CAA, the MPRSA's implications for development and deployment of NETs have been explored in a number of previous studies, including several focused specifically on ocean fertilization and other ocean-based CDR techniques (Branson, 2014; Richards, 2017; Silverman-Roati et al., 2022b; Webb et al., 2021, 2022). Some ocean CDR projects have reportedly avoided U.S. waters due to difficulties in securing permits under the MPRSA (Yu, 2023). These experiences could, again, be instructive for atmospheric methane removal projects.

4.3 Domestic Law Relevant to Closed Systems

As explained in Section 2.1 above, given the nature of closed atmospheric methane removal systems, their testing and deployment may implicate fewer legal frameworks than open systems. That does not, however, mean that no legal issues will arise. The crosscutting issues identified in Section 4.1 above—that is, relating to land use and environmental impacts—will need to be considered in connection with all future atmospheric methane removal projects including those using closed systems. Some closed system projects might also raise additional issues if, for example, they use inputs or generate by-products that could be a source of air or water pollution. As an illustration, in methane reactors, zeolites or another catalyst would be used to oxide methane in air, producing CO_2 and water in the process. Depending on the amount of CO_2 produced and how that CO_2 is handled, operation of the reactor may implicate the CAA. For example, the CAA's Greenhouse Gas Reporting Program (GHGRP) would apply if (1) the reactor emitted 25,000 metric tons or more of CO_2 per year or (2) if emissions were below that threshold but the operator captured and supplied CO_2 for commercial applications.[158] To meet the requirements of the GHGRP, the operator of the reactor would need to file annual reports with EPA detailing its greenhouse gas emissions. Also under the CAA, EPA has established CO_2 emissions standards for certain industrial facilities (e.g., power plants) (Lorenzen et al., 2023). While the current standards do not apply to methane reactors, if such reactors prove to be a large source of emissions in the future, EPA may consider establishing CO_2 emissions standards for them.

Along the same lines, if by-products produced by a closed atmospheric methane removal system are to be discharged into water bodies, that could trigger application of the CWA. As described above, the term "pollutant" in the CWA is defined broadly to mean "dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water."[159] The inclusion of "heat" is particularly significant and means that even if a closed system produces

---

[157] 33 U.S.C. § 1412.
[158] 40 C.F.R. Pt. 98.
[159] 33 U.S.C. § 1362.

water without any chemical contaminants, the discharge of that water may be regulated under the CWA if it results in thermal pollution. This could trigger the imposition of additional review and permit requirements.

Any waste materials from closed atmospheric methane removal systems would need to be managed in accordance with applicable laws. One example is the Resource Conservation and Recovery Act (RCRA), which regulates the handling, storing, and disposal of "solid waste," defined as any "discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining and agricultural operations."[160] RCRA establishes separate regulatory frameworks for hazardous waste (covered by subtitle C of the Act) and non-hazardous waste (covered by subtitle D), with stricter controls applying to the handling, storage, and disposal of the former. The nature of any waste produced by atmospheric methane removal systems—and, in particular, whether the waste presents hazards to human health and the environment—will thus affect the applicable regulatory requirements.

4.4 Liability Considerations under Domestic Law

Atmospheric methane removal project operators may face statutory and tort liability concerns under U.S. federal and state law. This may be especially true for open systems, where impacts are more likely to spread beyond a given project area and potentially onto neighboring land. Any assessment of liability would be heavily dependent on the specific facts of a particular atmospheric methane removal project, the location, the nature and scope of the alleged damages, and the source and extent of the statutory or common law obligation imposed on the project operator.

Several of the U.S. federal environmental statutes discussed above include liability provisions that impose fines and other penalties on those who violate the statues. These include, for example, the CAA, ESA, MBTA, and MPRSA (Hester, 2018a). Broadly, federal environmental laws impose civil liability on those who fail to comply with permit terms or other regulatory requirements. Some require agencies to consider evidence of fault or negligence when making enforcement decisions and, in particular, deciding whether to impose heightened financial liability and how to allocate liability among several parties (Hester, 2018a). Some environmental laws also impose criminal liability. For example, the CWA imposes criminal liability for simple negligence in violating some of its terms, and the ESA imposes broad criminal liability for knowingly taking endangered species (Hester, 2018a). The significant criminal and civil penalties associated with violating federal environmental laws in the United States underscore the importance of any atmospheric methane removal project proponent acting consistent with their terms.

Even where projects do not run afoul of federal environmental statutes, courts could, at least in theory, impose tort liability on project proponents if their actions cause harm to other

---

[160] 42 U.S.C. § 6903.

persons or their property. Actions to hold project proponents liable under tort law are most likely to arise under state law in state court and to assert causes of action like private or public nuisance, trespass, negligence, failure to warn, and strict liability for ultrahazardous activities (Hester, 2018a). While an analysis of the scope of liability stemming from tort actions is beyond the scope of this paper, a key question courts may assess is whether the harms resulting from a project are foreseeable. Plaintiffs in tort actions could face a number of jurisdictional and procedural obstacles in successfully persuading a court to find atmospheric methane removal project proponents liable (Hester, 2018a). However, if a court did find a project proponent liable, it might impose significant fines or an injunction stopping the project from moving forward.

The federal government and/or states could take a variety of steps to provide greater certainty to, and even limit the liability exposure of, atmospheric methane removal project developers. Congress has done this in other contexts, with a view to supporting research into emerging technologies (Hester, 2018b). For example, Congress has adopted liability caps for nuclear plant operators (Hester, 2018b). EPA has provided conditional waivers from hazardous waste regulations for CO_2 sequestration projects (Hester, 2018b). Some states have also sought to limit liability for CO_2 sequestration projects. For example, in Louisiana, legislation has been enacted to limit private liability for sequestration projects by transferring ownership of sequestered CO_2 to the state after 10 years (subject to certain requirements).[161] Similar liability waivers and limits could, in the future, be provided for atmospheric methane removal projects. However, based on past experience in other sectors, it seems likely that any such waivers or limits would include requirements with respect to the scientific integrity and impact of atmospheric methane removal projects. For example, state regimes designed to limit liability for CO_2 sequestration projects typically require the operator to show that it is in compliance with all applicable laws and regulations, that the storage formation meets certain requirements (e.g., with respect to integrity), that equipment and facilities are in good working order, and that any reclamation work has been completed, among others.[162]

5. CONCLUSION

While there is no specific legal regime governing atmospheric methane removal activities, a variety of general environmental and other U.S. and international laws may apply to field research and deployment. The applicability of different laws will depend on a range of factors, including the specific nature of the activities (e.g., whether they involve open or closed systems), the purpose for which they are conducted (e.g., whether they involve research or commercial activities), where they take place (e.g., on land or in the ocean), and the nature and location of their impacts.

---

[161] LA Rev. Stat. Ann. §§30:1109.
[162] See, for example, Mont. Code Ann. § 82-11-183; N.D. Cent. Code § 38-22-17; Wyo. Stat. Ann. § 35-11-319.

Under international law, atmospheric methane removal activities may be governed under both customary international law and international agreements. When proposing a project within a given country, project proponents should be cognizant of which agreements that country has consented to be bound by and the way that that country has codified its obligations under international law into domestic law. In addition, the decisions governing ocean fertilization and geoengineering adopted by parties to the CBD, London Convention, and London Protocol can shed light on the way international legal institutions and individual countries might be expected to treat atmospheric methane removal activities. These decisions are generally skeptical of deployment but allow legitimate scientific research projects to go forward if they meet certain requirements. The decisions are explicitly nonbinding but highly influential, and further international legal governance of atmospheric methane removal is likely to develop in the context of the decisions.

Under domestic U.S. law, atmospheric methane removal activities will need to comply with federal environmental laws, in addition to any tribal, state, and local laws relevant to a given project. Depending on the atmospheric methane removal approach, projects may be subject to permitting and other requirements under the CAA, CWA, ESA, FLPMA, MPRSA, and NEPA (among others). This patchwork approach to regulating atmospheric methane removal projects is likely to result in significant uncertainties and complexities for project developers. Legal reforms may, therefore, be useful or necessary to ensure efficient, safe, and responsible atmospheric methane removal research and deployment (if the latter is deemed appropriate).

As described throughout the paper, further research is needed into the legal framework applicable to atmospheric methane removal. Such research will be particularly important to identify U.S. tribal, state, and local legal frameworks and permitting requirements that are not addressed in this paper. Further research into the potential for tort liability for any harms resulting from research projects and later deployments (if any) is also needed. Once the existing legal landscape has been surveyed fully, research should be undertaken to assess the adequacy of existing legal frameworks and explore possible reforms to address any identified gaps or shortcomings in those frameworks. Complementary research into the policy landscape for atmospheric methane removal would also be useful. One way to approach the research would be to conduct detailed analyses of the legal issues associated with individual atmospheric methane removal approaches. This would allow for a more granular analysis of the relevant legal frameworks and permitting regimes and thus provide more detailed guidance for specific projects that involve use of specific atmospheric methane removal approaches. It would also help to identify gaps, shortcomings, or other inadequacies in existing legal frameworks and inform discussions about possible future legal reforms. This could, in turn, provide the basis for developing new legal rules to govern atmospheric methane removal activities.

Developing codes of conduct and ethical guidelines for atmospheric methane removal research could also help inform needed legal reforms and development of governance frameworks. There are currently a number of initiatives underway to develop codes of conduct and ethical guidelines for NETs and geoengineering activities, including two relevant recent

examples, which could help inform work on atmospheric methane removal. In 2022, the American Geophysical Union published ethical framework principles for climate intervention research, which identified principles around public participation, environmental justice, and data sharing, among others, that experiments should follow (AGU, 2022). In the ocean CDR context, in 2023, the Aspen Institute published a code of conduct, which developed foundational principles and specific recommendations for every phase of a research project (Boettcher et al., 2023). A similar effort undertaken for atmospheric methane removal experiments could provide valuable insights into the best way to develop an ethical and fair governance framework.

ANNEX A: LEGAL REQUIREMENTS FOR ATMOSPHERIC METHANE REMOVAL PROJECTS

Table 1 below lays out a nonexhaustive summary of key international and domestic (U.S.) legal requirements that may apply to atmospheric methane removal projects based on the nature of the activities they involve, where the activities take place, and the purpose of the project. The domestic law section of the table focuses on requirements imposed by U.S. federal law and does not address tribal, state, or local requirements fully. Note that this table is a summary of the information detailed in the report and should be read together with it. As noted in the report, further research is needed to map the full legal landscape for atmospheric methane removal activities; that research may identify additional requirements that are not reflected in this table.

TABLE 1 Key International and Domestic Legal Requirements That May Apply to Atmospheric Methane Removal Projects

Approach	**Location**	**Purpose**	**Key Legal Requirements (nonexhaustive)**	
			International	**Domestic (U.S.)**
Open system	On land	Research	- Under customary international law, country with jurisdiction over project must ensure that it does not cause transboundary environmental damage. EIA will be required if project poses a significant risk of such damage. - CBD may apply if country with jurisdiction over project is a party. Country must ensure that project does not cause transboundary environmental harm, and must comply with environmental review and other requirements of CBD. - Country with jurisdiction over project should ensure that it complies with 2010 CBD decision on geoengineering (if applicable). The decision will only apply if project involves "geoengineering activities that may affect biodiversity." Decision requires project to be "small-scale" and "conducted in a controlled setting." - Arctic Council agreement on scientific cooperation may apply if research is conducted in the Arctic region.	*The below requirements will apply to both research and deployment projects.* - Environmental review requirements under NEPA may apply if project is conducted, authorized, or funded by a federal agency. Similar environmental review requirements may also apply at the state and/or local levels. - ESA and other species protection laws may apply if project may affect listed endangered or threatened species. - BLM authorizations may be required if project will be sited on federal land. - State agricultural preservation laws may apply if project will be deployed on agricultural land. - CWA discharge permits may be required if the project will add pollutants to waters of the United States. But note that agricultural runoff is excluded from permit requirements.
		Deployment	- Customary international law requirements (described above) will apply. - CBD may apply if country with jurisdiction over project is a party. (Requirements described above will apply.)	

			- Country with jurisdiction over the project should prevent it from going ahead if it involves "geoengineering" and "may affect biodiversity" (consistent with the 2010 CBD decision on geoengineering).	- CAA permits may be required if the project will emit air pollutants.
	Ocean-based	Research	- Customary international law requirements (described above) will apply. - CBD may apply if country with jurisdiction over project is a party. (Requirements described above will apply.) Country with jurisdiction over project should ensure that it complies with 2010 CBD decision on geoengineering (if applicable). (Requirements described above will apply.) - UNCLOS rules on MSR may apply if country with jurisdiction over project is a party. Country must ensure that project has necessary permissions, is conducted in accordance with appropriate scientific methods, and does not unjustifiably interfere with other legitimate uses of the ocean. - London Convention and Protocol may apply if country with jurisdiction over project is a party and the project involves "dumping." Project would need to be permitted in accordance with London Convention and Protocol. o For projects involving ocean fertilization, country should ensure that requirements for legitimate scientific research are met. - Arctic Council agreement on scientific cooperation may apply if research is conducted in the Arctic region.	*The below requirements apply to both research and deployment projects. Note that research projects may qualify for research permits under the MPRSA (whereas deployments will require general or special permits).* - Environmental review requirements under NEPA may apply if project is conducted, authorized, or funded by a federal agency. Similar environmental review requirements by states may also apply at the state and/or local levels. - ESA and other species protection laws may apply if project may affect listed endangered or threatened species. - CAA permits may be required if the project will emit air pollutants. - MPRSA ocean dumping permits may be required if project involves the dumping of any material into ocean waters.
		Deployment	- Customary international law requirements (described above) will apply. - CBD may apply if country with jurisdiction over project is a party. (Requirements described above will apply.) - Country with jurisdiction over the project should prevent it from going ahead if it involves "geoengineering" and "may affect biodiversity" (consistent with the 2010 CBD decision on geoengineering).	

			- London Convention and Protocol may apply if country with jurisdiction over project is a party and the project involves "dumping." o If project involves ocean fertilization, country should prevent it from going ahead.	
Closed system[a]	On land	Research	- CBD may apply if country with jurisdiction over project is a party. (Requirements above will apply.) - Country with jurisdiction over project should ensure that it complies with 2010 CBD decision on geoengineering (if applicable). (Requirements described above will apply.) - Arctic Council agreement on scientific cooperation may apply if research is conducted in the Arctic region.	*The below requirements apply to both research and deployment projects.* - Environmental review requirements under NEPA may apply if project is conducted, authorized, or funded by a federal agency. Similar environmental review requirements may apply at the state and/or local levels. - ESA and other species protection laws may apply if project may affect listed endangered or threatened species. - BLM authorizations may be required if the project will be sited on federal land. - CAA permits may be required if project will emit air pollutants. - CWA discharge permits may be required if project will add pollutants to the waters of the United States. - RCRA may apply to handling, storage, and disposal of waste from the project.
		Deployment	- CBD may apply if country with jurisdiction over project is a party. (Requirements above will apply.) - Country with jurisdiction over the project should prevent it from going ahead if it involves "geoengineering" and "may affect biodiversity" (consistent with the 2010 CBD decision on geoengineering).	
	Ocean-based	Research	N/A	N/A
		Deployment	N/A	N/A

[a] Note that this section assumes that closed system projects are not likely to cause transboundary environmental damage. If projects do have such effects, more legal obligations will be imposed.

REFERENCES

AGU (American Geophysical Union). (2022). *Ethical framework principles for climate intervention research*. https://www.agu.org/-/media/Files/Learn-About-AGU/Ethical-Framework-Climate-Intervention/AGU-Ethical-Framework-Draft-Principles.pdf

Boettcher, M., Chai, F., Cooley, S., Klinsky, S., Renforth, P., Webb, R., Conathan, M., Keller, D., Lazaun, J., & Scobie, M. (2023). *A code of conduct for marine carbon dioxide removal research*. Aspen Institute. https://www.aspeninstitute.org/wp-content/uploads/2023/11/110223_Code-of-Conduct_FINAL2.pdf

Branson, M. (2014). A green herring: How current ocean fertilization regulation distracts from geoengineering research. *Santa Clara Law Review*, *54*(1), 163.

Brent, K., Burns, W., & McGee, J. (2019). *Governance of marine geoengineering*. Centre for International Governance Innovation. https://www.cigionline.org/publications/governance-marine-geoengineering/

Burns, W. (2023). Governance of ocean-based carbon dioxide removal research under the United Nations Conventions on the Law of the Sea. *Maine Law Review*, *75*(1), 37.

Burns, W., & Webb, R. M. (2023). The Biodiversity Beyond National Jurisdiction Treaty and its implications for marine-based carbon dioxide removal. *Illuminem*. https://illuminem.com/illuminemvoices/the-biodiversity-beyond-national-jurisdiction-treaty-and-its-implications-for-marinebased-carbon-dioxide-removal

Council on Environmental Quality. (n.d.). *States and local jurisdictions with NEPA-like environment planning requirements*. NEPA.GOV: National Environmental Policy Act. Retrieved September 29, 2023, from https://ceq.doe.gov/laws-regulations/states.html

Craik, A., & Burns, W. (2016). *Climate engineering under the Paris Agreement: A legal and policy primer*. Centre for International Governance Innovation.

Eisenson, M., & Webb, R. (2023). *Expert insights on best practices for community benefits agreements*. Sabin Center for Climate Change Law. https://scholarship.law.columbia.edu/sabin_climate_change/206

EPA (Environmental Protection Agency). (n.d.-a). *Learn about ocean dumping*. Retrieved September 29, 2023, from https://www.epa.gov/ocean-dumping/learn-about-ocean-dumping#incineration

EPA. (n.d.-b). *National ambient air quality standards (NAAQS) for PM*. Retrieved September 29, 2023, from https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm#:~:text=Currently%2C%20EPA%20has%20primary%20and,150%20%C2%B5g%2Fm3

EPA. (1987). *Ocean incineration: Background and status*. https://nepis.epa.gov/Exe/ZyNET.exe/9100OOPF.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000026%5C9100OOPF.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

EPA. (2023a). *Ocean dumping: International treaties*. https://www.epa.gov/ocean-dumping/ocean-dumping-international-treaties#US%20LC%20Contracting%20Party

EPA. (2023b). *StarKist Samoa Co., American Samoa*. https://www.epa.gov/ocean-dumping/starkist-samoa-co-american-samoa

Gallo, N. D., Victor, D. G., & Levin, L. A. (2017). Ocean commitments under the Paris Agreement. *Nature Climate Change*, *7*(11), 833–838. https://doi.org/10.1038/nclimate3422

Green, J. A. (2016). *The persistent objector rule in international law*. Oxford University Press. https://doi.org/10.1093/law/9780198704218.001.0001

Hester, T. (2018a). Legal pathways to negative emissions technologies and direct air capture of greenhouse gases. *Environmental Law Reporter*, *48*. https://www.law.uh.edu/faculty/thester/courses/Climate%20Intervention%20Law%202019/Legal%20Pathways%20to%20Broad%20Use%20of%20NETs%20and%20DAC%20by%20Hester.pdf

Hester, T. (2018b). Liability and compensation. In M. B. Gerrard & T. Hester (Eds.), *Climate engineering and the law* (1st ed., pp. 224–268). Cambridge University Press. https://doi.org/10.1017/9781316661864.005

Honegger, M., Burns, W., & Morrow, D. R. (2021). Is carbon dioxide removal "mitigation of climate change"? *Review of European, Comparative & International Environmental Law*, *30*(3), 327–335. https://doi.org/10.1111/reel.12401

Horton, J., Keith, D., & Honeggar, M. (2016). *Implications of the Paris Agreement for carbon dioxide removal and solar geoengineering*. Harvard Project on Climate Agreements. https://keith.seas.harvard.edu/files/tkg/files/horton_et_al._-_2016_-_implications_of_the_paris_agreement_for_carbon_dio.pdf

International Law Commission. (2001). *Draft articles on prevention of transboundary harm from hazardous activities*. International Law Commission. https://legal.un.org/ilc/texts/instruments/english/commentaries/9_7_2001.pdf

Keiper, F., & Atanassova, A. (2020). Regulation of synthetic biology: Developments under the Convention on Biological Diversity and its protocols. *Frontiers in Bioengineering and Biotechnology*, *8*, 310. https://doi.org/10.3389/fbioe.2020.00310

Krug, J. H. A. (2018). Accounting of GHG emissions and removals from forest management: A long road from Kyoto to Paris. *Carbon Balance and Management*, *13*(1), 1. https://doi.org/10.1186/s13021-017-0089-6

Lorenzen, T., Meyers, R., Shafer Berman, A., & Dawson, E. B. (2023). Regulation of greenhouse gases under the Clean Air Act. In M. B. Gerrard, J. Freeman, & M. Burger (Eds.), *Global climate change and U.S. law*. American Bar Association.

Mar, K. A., Unger, C., Walderdorff, L., & Butler, T. (2022). Beyond CO_2 equivalence: The impacts of methane on climate, ecosystems, and health. *Environmental Science & Policy*, *134*, 127–136. https://doi.org/10.1016/j.envsci.2022.03.027

Pacyniak, G. (2023). State sequestration: Federal policy accelerates carbon storage, but leaves full climate, equity protections to states. *San Diego Journal of Climate & Energy Law*, *95*. https://deliverypdf.ssrn.com/delivery.php?ID=745086022072103119015082007112104011033038073093037044085070069124097010092027118065023050121119108017105121077120025064122112103053093022043090001025094088083030024041036013013023101097102082105014070011004097114114098094102023019094089094106002089084&EXT=pdf&INDEX=TRUE

Parker, G. (2022, January 3). Carbon, capture, and storage: History, current state, and obstacles for the future (Part 2) [Environmental Law Institute]. *Vibrant Environment Blog*. https://www.eli.org/vibrant-environment-blog/carbon-capture-and-storage-history-current-state-and-obstacles-future-part-2

Pennsylvania Land Trust Association, Loza, A., & Theilacker, J. (2013). *Agricultural protection zoning*. We Conserve PA. https://conservationtools.org/guides/67-Agricultural-Protection-Zoning

Proelss, A. (2021). Law of the Sea and geoengineering. In *Law of the Sea: Normative context and interactions with other legal regimes*. Routledge.

Proelss, A., & Hong, C. (2012). Ocean upwelling and international law. *Ocean Development & International Law*, *43*(4), 371–385. https://doi.org/10.1080/00908320.2012.726843

Proelss, A., & Steenkamp, R. C. (2022). Geoengineering: Methods, associated risks and international liability. In P. Gailhofer, D. Krebs, A. Proelss, K. Schmalenbach, & R. Verheyen (Eds.), *Corporate liability for transboundary environmental harm: An international and transnational perspective* (pp. 419–503). Springer International Publishing. https://doi.org/10.1007/978-3-031-13264-3_9

Reynolds, J. (2016). Climate engineering and international law. In D. Farber & M. Peeters (Eds.), *Climate change law* (p. 178). Edward Elgar Publishing. https://doi.org/10.4337/9781785369520

Reynolds, J. (2018). International law. In M. Gerrard & T. Hester (Eds.), *Climate engineering and the law: Regulation and liability for solar radiation management and carbon dioxide removal*. Cambridge University Press. https://scholarship.law.columbia.edu/books/59

Reynolds, J. L. (2019). Solar geoengineering to reduce climate change: A review of governance proposals. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *475*(2229), 20190255. https://doi.org/10.1098/rspa.2019.0255

Richards, J. (2017). It's getting hot in here: A look into whether ocean iron fertilization is legally viable in the United States. *Science and Technology Law*, *18*(2), 73–107.

Silverman-Roati, K., Webb, R., & Gerrard, M. (2022a). *Permitting seaweed cultivation for carbon sequestration in California: Barriers and recommendations.* Sabin Center for Climate Change Law. https://scholarship.law.columbia.edu/faculty_scholarship/3523

Silverman-Roati, K., Webb, R., & Gerrard, M. (2022b). *Removing carbon dioxide through ocean fertilization: Legal challenges and opportunities.* Sabin Center for Climate Change Law. https://scholarship.law.columbia.edu/faculty_scholarship/3637

Stephens, T., & Rothwell, D. (2016). Marine scientific research. In D. Rothwell, A. Oude Elferink, K. Scott, & T. Stephens (Eds.), *The Oxford handbook of the Law of the Sea* (pp. 559–581). Oxford University Press. https://doi.org/10.1093/law/9780198715481.003.0025

UN (United Nations). (n.d.-a). *Montreal protocol on substances that deplete the ozone layer* (United Nations Treaty Series). Retrieved October 1, 2023, from https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-2-a&chapter=27&clang=_en

UN. (n.d.-b). *Parties to the United Nations Framework Convention on Climate Change* (United Nations Climate Change). Retrieved September 19, 2023, from https://unfccc.int/process/parties-non-party-stakeholders/parties-convention-and-observer-states

UN. (2023a). *Agreement under the United Nations convention on the law of the sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdictions* (United Nations Treaty Series). https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXI-

10&chapter=21&clang=_en&_gl=1*1uvdod9*_ga*MTYxNTk2NDU0LjE2NzM5NTE0MjY.*_ga_TK9BQL5X7Z*MTY5NjM1NTUyMC4xMi4wLjE2OTYzNTU1MjcuMC4wLjA

UN. (2023b). *United Nations convention on the law of the sea* (United Nations Treaty Series). https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXI-6&chapter=21&Temp=mtdsg3&lang=en

UN. (2023c). *United Nations Convention on the Law of the Sea of 10 December 1982: Overview and full text*. https://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm

UN Environment Programme. (n.d.). *List of parties*. Convention on Biological Diversity. Retrieved September 19, 2023, from https://www.cbd.int/information/parties.shtml

UN Environment Programme. (2018). *Parties to the Cartagena Protocol and its supplementary protocol on liability and redress*. Convention on Biological Diversity. https://bch.cbd.int/protocol/parties/#tab=1

UNECE (United Nations Economic Commission for Europe). (n.d.). *The Convention and its achievements*. Retrieved December 22, 2023, from https://unece.org/convention-and-its-achievements

U.S. Department of the Interior. (2009). *Report to Congress: Framework for geological carbon sequestration on public lands.* U.S. Department of the Interior.

U.S. Department of State. (n.d.-a). *Convention on long-range transboundary air pollution*. Retrieved December 13, 2023, from https://www.state.gov/key-topics-office-of-environmental-quality-and-transboundary-issues/convention-on-long-range-transboundary-air-pollution/

U.S. Department of State. (n.d.-b). *Law of the sea convention*. Retrieved September 28, 2023, from https://www.state.gov/law-of-the-sea-convention/

Vincent, C., Hanson, L., & Bermejo, L. (2020). *Federal land ownership: Overview and data.* Congressional Research Service. https://sgp.fas.org/crs/misc/R42346.pdf

Voigt, C., Virkkala, A.-M., Hould Gosselin, G., Bennett, K. A., Black, T. A., Detto, M., Chevrier-Dion, C., Guggenberger, G., Hashmi, W., Kohl, L., Kou, D., Marquis, C., Marsh, P., Marushchak, M. E., Nesic, Z., Nykänen, H., Saarela, T., Sauheitl, L., Walker, B., … Sonnentag, O. (2023). Arctic soil methane sink increases with drier conditions and higher ecosystem respiration. *Nature Climate Change*, *13*(10), 1095–1104. https://doi.org/10.1038/s41558-023-01785-3

Webb, R. (2020, September). *The law of enhanced weathering for carbon dioxide removal.* Sabin Center for Climate Change Law, Columbia Law School. https://scholarship.law.columbia.edu/sabin_climate_change/46

Webb, R. (2023, September 28). The evolving legal landscape for ocean-based carbon dioxide removal. *Climate Law Blog.* https://blogs.law.columbia.edu/climatechange/2023/09/28/the-evolving-legal-landscape-for-ocean-based-carbon-dioxide-removal/

Webb, R., & Silverman-Roati, K. (2023). *Executive actions to ensure safe and responsible ocean carbon dioxide removal research in the United States.* Sabin Center for Climate Change Law. https://scholarship.law.columbia.edu/sabin_climate_change/211

Webb, R., Silverman-Roati, K., & Gerrard, M. (2021, February). *Removing carbon dioxide through ocean alkalinity enhancement and seaweed cultivation: Legal challenges and opportunities.* Sabin Center for Climate Change Law, Columbia Law School. https://scholarship.law.columbia.edu/faculty_scholarship/2739

Webb, R., Silverman-Roati, K., & Gerrard, M. (2022). *Removing carbon dioxide through artificial upwelling and downwelling: Legal challenges and opportunities.* Sabin Center for Climate Change Law. https://scholarship.law.columbia.edu/faculty_scholarship/3337/

Webb, R. M., Silverman-Roati, K., & Gerrard, M. B. (2023). International laws governing ocean CDR. In R. M. Webb, K. Silverman-Roati, & M. B. Gerrard (Eds.), *Ocean carbon dioxide removal for climate mitigation: The legal framework*. Edward Elgar Publishing. https://www.e-elgar.com/shop/usd/ocean-carbon-dioxide-removal-for-climate-mitigation-9781802208849.html

WMO (World Meteorological Organization). (2022). *Scientific assessment of ozone depletion: 2022: Executive summary* World Meteorological Organization. https://ozone.unep.org/system/files/documents/Scientific-Assessment-of-Ozone-Depletion-2022-Executive-Summary.pdf

Yu, J. (2023, June 28). Ocean CDR permitting and regulations 101. *ClearPath Tech 101*. https://clearpath.org/tech-101/ocean-cdr-permitting-and-regulations-101/