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International Governance of Ocean Iron Fertilization Research: A Case Study of the Proposed Exploring Ocean Iron Solutions Field Experiments

Ashwin Murthy

Romany M. Webb

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**INTERNATIONAL GOVERNANCE OF OCEAN IRON FERTILIZATION
RESEARCH: A CASE STUDY OF THE PROPOSED EXPLORING OCEAN
IRON SOLUTIONS FIELD EXPERIMENTS**



FEBRUARY 2026

Ashwin Murthy and Romany M. Webb

Columbia Law School, Sabin Center for Climate Change Law

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Sabin Center for Climate Change Law Columbia Law School
435 West 116th Street
New York, NY 10027
Tel: +1 (212) 854-3287
Email: columbiaclimate@gmail.com
Web: <https://climate.law.columbia.edu/>
Blog: <http://blogs.law.columbia.edu/climatechange>

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About the Authors: Ashwin Murthy is a Negative Emissions Fellow at the Sabin Center for Climate Change Law. Romany M. Webb is the Deputy Director of the Sabin Center, Research Scholar at Columbia Law School, Adjunct Assistant Professor of Climate at the Columbia Climate School, and Senior Advisor on Climate Science at the Columbia Graduate School of Journalism.

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Cover Image: *Newly Published Article Outlines Case for Considering Adding Iron to the Ocean for Carbon Dioxide Removal*, WOODS HOLE OCEANOGRAPHIC INSTITUTION, www.whoi.edu/press-room/news-release/exois-project/.

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1. INTRODUCTION

Ocean iron fertilization (OIF) has been a subject of scientific research since the 1980s. At least 13 in-ocean experiments involving the addition of iron to ocean waters were conducted between 1993 and 2009.¹ Beginning in the 2000s, there were also proposals for commercial projects, which attracted significant attention and concern from the international community.² In 2007, Planktos Corporation announced that plans to carry out OIF off the coast of the Galapagos Islands with the goal of generating carbon credits for sale. The project, which was met with significant opposition from the scientific community and environmental organizations, did not ultimately go ahead.³ However, another commercial project was undertaken in 2012, when the Haida Salmon Restoration Corporation dispersed 100 tons of iron sulphate dust off the coast of Canada with the stated purpose of enhancing salmon stocks.⁴ These activities prompted questions about the adequacy of international governance of OIF and ultimately led the international community to develop a new framework therefor.

The primary international legal instruments regulating OIF are the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention or LC) and the 1996 Protocol to that Convention (London Protocol or LP). The LC was adopted to address ocean pollution; its stated objective is to “promote the effective control of all sources of pollution of the marine environment, and ... especially ... to prevent the pollution of the sea by dumping.”⁵ At the time of writing, 87 countries are parties to the LC (known as Contracting Parties or Parties).⁶

In 1996, the Contracting Parties to the LC negotiated a new stand-alone agreement – the LP – which was intended to replace the Convention.⁷ However, while the LP entered into force in 2006, it has not replaced the LC.⁸ Rather,

¹ JOINT GROUP OF EXPERTS ON THE SCIENTIFIC ASPECTS OF MARINE ENVIRONMENTAL PROTECTION (GESAMP), HIGH LEVEL REVIEW OF A WIDE RANGE OF PROPOSED MARINE GEOENGINEERING TECHNIQUES (2019) 45, <http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques>.

² David Biello, *Can Controversial Ocean Iron Fertilization Save Salmon*, SCIENTIFIC AMERICAN (Oct. 24, 2012), <https://www.scientificamerican.com/article/fertilizing-ocean-with-iron-to-save-salmon-and-earn-money/>.

³ *Planktos Kills Iron Fertilization Project Due to Environmental Opposition*, MONGABAY (Feb. 19, 2008), <https://news.mongabay.com/2008/02/planktos-kills-iron-fertilization-project-due-to-environmental-opposition/>.

⁴ *B.C. Village’s Ocean Fertilization Experiment Probed*, GEOENGINEERING MONITOR (Mar. 28, 2013), <https://www.geoengineeringmonitor.org/b-c-villages-ocean-fertilization-experiment-probed>.

⁵ Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Dec. 29, 1972 [hereinafter “LC”], Art. 1.

⁶ LC 1046 U.N.T.S. I-15749 at 154, <https://treaties.un.org/doc/Publication/UNTS/Volume%201046/volume-1046-I-15749-English.pdf> (the list of contracting parties can also be found at <https://treaties.un.org/pages/showDetails.aspx?objid=08000002800fdd18>).

⁷ Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, Nov. 7, 1996 [hereinafter “LP”].

⁸ For the LP to replace the LC, it must be ratified by all of the parties to the LP. At the time of writing, 46 parties to the LC have not ratified the LP. *Status of IMO Treaties*, IMO, <https://www.imo.org/en/About/Conventions/Pages/StatusOfConventions.aspx> (last accessed on Sept. 15, 2025).

the two instruments operate in parallel. The LP is binding on 56 countries that have formally ratified or otherwise adopted it.⁹ Other countries that are party to the LC, but have not ratified the LP, are bound only by the Convention.¹⁰

The Contracting Parties to the LC and LP have considered OIF several times over the last three decades. In 2007, in response to the Planktos proposal, the Scientific Groups of the LC and LP issued a “Statement of Concern” regarding OIF. The statement concluded that “knowledge about the effectiveness and potential environmental impacts of [OIF] currently was insufficient to justify large-scale operations,” and “recommended that any such operations be evaluated carefully to ensure, among other things, that [they] were not contrary to the aims of” the LC and LP.¹¹

In 2008, the Contracting Parties to the LC and LP adopted Resolution LC-LP.1 which concluded that, “given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed.”¹² The 2008 Resolution called for the development of an “assessment framework” to be used in evaluating proposed OIF research projects. In 2009, the Scientific Groups of the LC and LP issued a draft “Assessment Framework for Scientific Research Involving Ocean Fertilization” (Assessment Framework). That framework was adopted by the Contracting Parties to the LC and LP in 2010 in Resolution LC-LP.2(2010).¹³

The 2008 and 2010 Resolutions are not legally binding. The Parties to the LP have adopted an amendment in 2013 addressing OIF that is intended to be legally binding but has not yet entered into force. The amendment requires Parties to the LP to prohibit the placement of matter in the ocean for “marine geoengineering activities listed in annex 4, unless the listing provides that the activity ... may be authorized under a permit.”¹⁴ At the time of writing, annex 4 only lists OIF and provides that LP Parties may only issue permits for OIF activities that are “assessed as constituting legitimate scientific research.”¹⁵ The amendment incorporates a framework for assessing proposed research projects that mirrors the 2010 Assessment Framework.¹⁶ In effect, then, the 2013

⁹ *Id.*

¹⁰ For example, the United States is a Contracting Party to the LC, but has not ratified the LP. *Ocean Dumping: International Treaties*, EPA, https://19january2021snapshot.epa.gov/ocean-dumping/ocean-dumping-international-treaties_.html.

¹¹ Statement of concern regarding iron fertilization of the oceans to sequester CO₂, 30th Meeting of the Scientific Group under the London Convention, LC-LP.1/Circ.14, Ref. T5/5.01, July 13, 2007.

¹² Resolution LC-LP.1 (2008) on the Regulation of Ocean Fertilization, cl 8.

¹³ Resolution LC-LP.2 (2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization (Oct. 14, 2010).

¹⁴ Resolution LP.4(8) on the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and other Marine Geoengineering Activities (Oct. 18, 2013); LP, art 6*bis*. Working Group 41 of GESAMP have been developing an amended Integrated Assessment Framework, however it is unclear what changes are being proposed and the timeline for its development. *Ocean Interventions for Climate Change Mitigation*, GESAMP (May 16, 2025), <http://www.gesamp.org/work/groups/41>.

¹⁵ *Id.*

¹⁶ *Id.*

amendment allows OIF research projects that meet the requirement of the Assessment Framework to move forward but prohibits other OIF activities.¹⁷

No OIF projects have been undertaken in the ocean since these developments in the international governance framework. There is, thus, no real-world experience with applying the Assessment Framework. Given the non-binding nature of the Assessment Framework, it will ultimately be up to the country overseeing a proposed OIF project to determine whether and how to apply the Framework. Nevertheless, the Assessment Framework is expected to be relied upon by at least some Parties to the LC and LP. Both Canada and the U.S., for example, have indicated that they will apply the Assessment Framework in evaluating OIF projects.¹⁸

To demonstrate how domestic regulators might use the Assessment Framework, this paper explores its application to recently proposed OIF field trials advanced by the Exploring Ocean Iron Solutions (ExOIS) research consortium. The ExOIS group aims to evaluate whether OIF is a feasible approach for removing and durably storing carbon dioxide from the atmosphere.¹⁹ Through the proposed field trials, currently planned to take place in the Gulf of Alaska, the group will test the feasibility, cost, and impact of large-scale OIF implementation.²⁰

In this paper, the ExOIS field trials are presented as a “case study” to illustrate how the Assessment Framework is likely to be applied in real-world settings.²¹ This is useful beyond the ExOIS project. Among other things, it provides OIF and other mCDR researchers with a guide to the information they will need to provide to domestic regulators applying the Assessment Framework, the key steps in the assessment, and questions and issues that might arise. The study also reveals challenges that domestic regulators might face in applying the Assessment Framework and offers recommendations for improving it.

This paper is organized as follows: Part 2 introduces the LC and LP and discusses the governance of OIF under the LC and LP. Part 3 describes the Assessment Framework and explores how the ExOIS field trial fits within the framework. Part 4 concludes by highlighting key gaps and challenges in applying the Assessment Framework and recommends changes to improve the regulation of OIF.

¹⁷ It should be noted that the 2013 Amendment has not yet entered into force and, even when it does, it will only bind countries that are Party to the LP (and not countries that are Party only to the LC).

¹⁸ See e.g., *Disposal at Sea: Ocean Fertilization Information for Research Community*, ENVIRONMENT AND CLIMATE CHANGE CANADA (May 27, 2025), <https://www.canada.ca/en/environment-climate-change/services/disposal-at-sea/publications/ocean-fertilization-information-research-community.html>.

¹⁹ Ken O. Buesseler *et al*, *The Case for Ocean Iron Fertilization Field Trials*, DIALOGUES ON CLIMATE CHANGE (2026), <https://journals.sagepub.com/doi/10.1177/29768659261420631>.

²⁰ *Id.*

²¹ The study was undertaken purely for academic purposes. The authors of this paper are not serving as legal counsel to the ExOIS team and are not involved in securing any necessary permits or other approvals for the field trial.

2. TREATMENT OF OCEAN FERTILIZATION UNDER THE LONDON CONVENTION AND PROTOCOL

2.1. Introduction to the London Convention and Protocol

Both the LC and LP require Contracting Parties to adopt domestic legislation to control “dumping,” which is defined as “any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea” (with limited exceptions).²² All such dumping must be permitted by the country under whose jurisdiction it occurs. Under Article VII of the LC and Article 10 of the LP, a country has jurisdiction to issue a permit for dumping where: (1) the vessel used for dumping is registered with the country or flies the country’s flag; (2) the material to be dumped is loaded in the country’s territory; or (3) the materials are dumped in ocean waters under the country’s jurisdiction (i.e., typically within 200 nautical miles of the country’s shores).²³ For example, under the U.S. law implementing the LC domestically, a permit is required from the U.S. if the ship to be used for dumping was registered with the U.S., if the materials to be dumped were loaded in the U.S., or if the materials are dumped within 12 nautical miles of the U.S. coast.²⁴

The LC and LP each establish different rules for the issuance of permits. Generally speaking, the LC is more permissive, authorizing Contracting Parties to issue permits for the dumping of any material, except for 8 substances that are listed in annex 1 to the Convention.²⁵ The 8 blacklisted substances are: (i) organohalogen compounds; (ii) mercury and mercury compounds; (iii) cadmium and cadmium compounds; (iv) persistent plastics and other persistent synthetic materials which may float or may remain in suspension in the sea in such a manner as to interfere materially with fishing, navigation or other legitimate uses of the sea; (v) crude oil and its wastes, refined petroleum products, petroleum, distillate residues, and any mixtures containing any of these,

²² LC, art III.1(a).

²³ LC, art VII.1. Coastal countries’ jurisdiction over ocean waters is defined under international law, as set out in the United Nations Convention on the Law of the Sea (UNCLOS). The U.S. is not a party to the UNCLOS but recognizes portions of it, including the provisions defining countries offshore jurisdiction, as forming part of customary international law. In line with the UNCLOS, the U.S. has claimed jurisdiction over ocean waters extending at least 200 nautical miles (n.m.) from the baseline. See U.N. Convention of the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397 [hereinafter UNCLOS], Article 2; Proclamation No. 5030, 48 Fed. Reg. 10605 (Mar. 14, 1983).

²⁴ 33 U.S.C. § 1401.

²⁵ LC, Annex 1; LC, art IV(1)(a).

taken on board for the purpose of dumping; (vi) radioactive wastes or other radioactive matter; (vii) materials in whatever form produced for biological and chemical warfare; and (viii) certain forms of industrial waste.²⁶

The LP imposes greater restrictions on when permits may be issued for dumping. Contracting Parties to the LP can only issue permits for the dumping of 8 listed substances, and must prohibit the dumping of all other, unlisted materials.²⁷ The 8 substances for which dumping permits may be issued are: (i) dredged material; (ii) sewage sludge; (iii) fish waste, or material resulting from industrial fish processing operations; (iv) vessels and platforms or other man-made structures at sea; (v) inert, inorganic geological material; (vi) organic material of natural origin; (vii) bulky items primarily comprising iron, steel, concrete and similarly unarmful materials for which the concern is physical impact, and limited to those circumstances where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than dumping; and (viii) carbon dioxide streams from carbon dioxide capture processes for sequestration.²⁸

2.2. Permitting OIF Under the London Convention and Protocol

There has long been a debate as to whether and when OIF might qualify as dumping and thus require a permit under the LC and LP. The definition of dumping in both instruments expressly excludes any “placement of matter [in the sea] for a purpose other than mere disposal thereof, provided that such placement is not contrary to the aims of” the LC and LP.²⁹ The Parties to the LC and LP have concluded that some OIF research projects may fall within this exception, but others may involve “dumping” as defined in the two instruments.

In the 2008 Resolution, Parties to the LC and LP agreed that “the scope of the London Convention and Protocol includes ocean fertilization activities.”³⁰ Notably, however, they went on to conclude that “legitimate scientific research [into OIF] should be regarded as placement of matter for a purpose other than mere disposal thereof.”³¹ The 2008 Resolution further stated that projects that qualify as “legitimate scientific research” should be evaluated “on a case-by-case basis” to determine whether they are “contrary to the aims of the” LC and LP.

²⁶ LC, Annex 1. “Industrial waste” means “waste materials generated by manufacturing or processing operations and does not apply to: (a) dredged material; (b) sewage sludge; (c) fish waste, or organic materials resulting from industrial fish processing operations; (d) vessels and platforms or other man-made structures at sea, provided that material capable of creating floating debris or otherwise contributing to pollution of the marine environment has been removed to the maximum extent; (e) uncontaminated inert geological materials the chemical constituents of which are unlikely to be released into the marine environment; (f) uncontaminated organic materials of natural origin.”

²⁷ LP, Annex 1.

²⁸ LP, Annex 1.

²⁹ LC, art III.1(b); LP, art 1.4.2.

³⁰ *Supra* n.12, cl 1.

³¹ *Id.*

Research projects that are deemed to be not contrary to the aims of the LC and LP will fall outside the definition of “dumping” in those instruments.

The 2008 Resolution also declared that other OIF projects, including commercial deployments, should be treated as dumping. Nevertheless, even where OIF is considered dumping, parties to the LC likely could issue permits for it, since iron is not included among the blacklisted substances identified in annex I to the Convention. However, given the “reserve listing” approach taken in the LP, parties to that instrument may not be able to permit OIF projects that are viewed as dumping. As noted above, parties to the LP can only issue permits for the dumping of listed substances, and the iron form used in OIF does not qualify.³²

The 2010 Assessment Framework is intended to guide countries in determining whether an OIF project qualifies as legitimate scientific research and whether it is, or is not, contrary to the aims of the LC and LP.³³ According to the Framework, a “decision that a proposed activity is legitimate scientific research and is not contrary to the aims of the [LC and LP] should only be made ... [if] conditions are in place that ensure that, as far as practicable, environmental disturbance and detriment would be minimized and the scientific benefits maximized.”³⁴

3. THE ASSESSMENT FRAMEWORK PROCESS

The Assessment Framework provides for a case-by-case review of proposed OIF projects. The review involves two distinct phases: first, there is an Initial Assessment focused on whether the “proposed activity falls within the definition of ocean fertilization and has proper scientific attributes” to be considered legitimate scientific research; and second, there is an Environmental Assessment that seeks to identify and evaluate environmental risks associated with the activity.³⁵ The stated goal of the Assessment Framework is to “ensure that, as far as

³² In our view, the iron used in OIF is unlikely to qualify as “inert, inorganic geological material.” In this regard, we note that Environment and Climate Change Canada (ECCC)—i.e., the Canadian federal government agency charged with implementing the LP—has indicated that material will only be considered “geological” if it has not been “altered from its original state by physical or chemical processing in a way that would result in different or additional impacts to the marine environment, compared with those expected from unaltered material.” ECCC has further states that, in determining whether something is “inert,” one must consider “both the pre-disposal nature of the material, and any alterations to it that may occur as a result of physical, chemical, or biological processes in the sea, are the only effects of concern those resulting from the physical properties of the material?” If the answer is yes, then the material is inert. Iron as is used in OIF would be physically altered (by being ground down into fine particles) to increase its impact to the marine environment, and would cause alterations beyond those resulting from its physical properties, implying that it would be considered neither inert nor geological, and therefore would not fall under Annex 1 of the LP. See *Disposal at Sea Permit Guide*, GOVERNMENT OF CANADA, <https://www.canada.ca/en/environment-climate-change/services/disposal-at-sea/permit-applicant-guide/excavated-material/excavated-waste-material-characterization.html>.

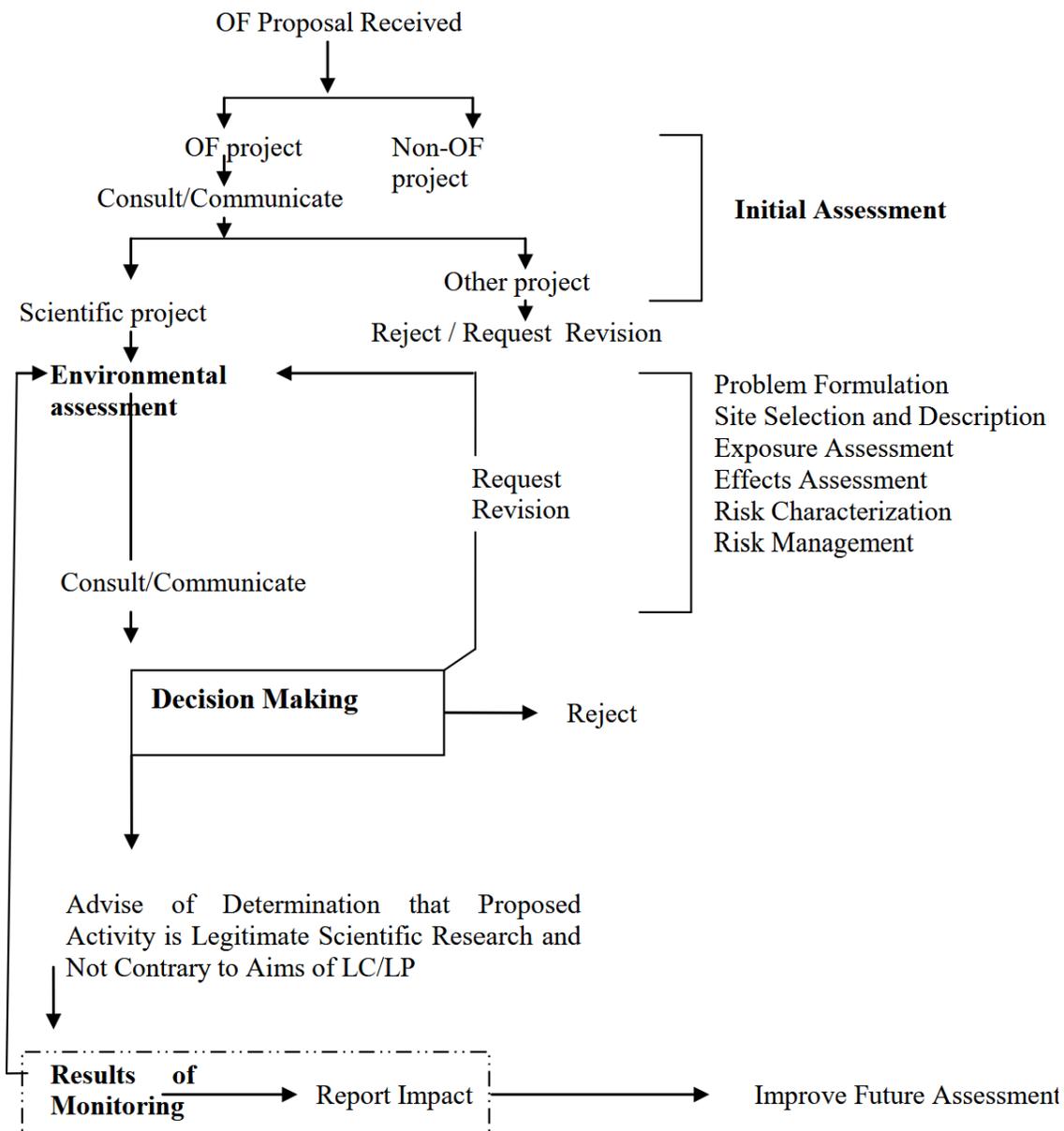
³³ Resolution LC-LP.2 (2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization (Oct. 14, 2010), Annex 6 [hereinafter “AF”].

³⁴ AF 4.1.

³⁵ AF 1.3; AF 4.1.

practicable, environmental disturbance [from OIF research] would be minimized and the scientific benefits maximized.”³⁶

A flowchart of the Assessment Framework process can be found below in Figure 1.



³⁶ AF 4.1.

Figure 1: Assessment Framework for Scientific Research Involving Ocean Fertilization³⁷

3.1. Initial Assessment

A proposed project must first demonstrate that it involves “ocean fertilization,” which is defined as “any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans.”³⁸ The ExOIS field trial aims to assess whether OIF is a feasible method of CDR and, as such, will involve the addition of iron to the ocean to stimulate primary productivity and thereby increase carbon uptake and storage. It would thus fall squarely within the definition of ocean fertilization.

To qualify as “legitimate scientific research,” proposed OIF projects must have four key scientific attributes, as follows:

- **Add to scientific knowledge:** According to the Assessment Framework, the proposed activity should “be designed to answer questions that will add to the body of scientific knowledge.”³⁹ The proposal should specify the activity’s “rationale, research goals, scientific hypotheses and methods, scale, timings and locations with clear justification for why the expected outcomes cannot reasonably be achieved by other methods.”⁴⁰ Materials published by the ExOIS Research Consortium, including a recent article in *Dialogues on Climate Change*,⁴¹ address these requirements, but further details could be provided on why this study is required and why its objectives could not be achieved by other methods.⁴²
- **No financial or economic gain:** The Assessment Framework states that “[e]conomic interests should not influence the design, conduct and/or outcomes of the proposed activity” and “[t]here should not be any financial and/or economic gain arising directly from the experiment or its outcomes.”⁴³ No further guidance is provided on when a project will be viewed as giving rise to “financial and/or economic gain.” It appears that the Parties intended to capture projects (like the one proposed by Planktos) that involve the sale of carbon credits. But questions remain as to whether all such projects are captured. For example, if proceeds from credit sales are used to cover project costs but there is no profit, can there be said to be “financial and/or economic gain” from the project? What about projects that are funded through other private channels (e.g., by venture capital funds), or projects with mixed sources of funding

³⁷ AF, Figure 1, p.4.

³⁸ AF 1.1.

³⁹ AF 2.2.1.

⁴⁰ AF 2.2.1.

⁴¹ *Supra* n.19.

⁴² AF 2.2.1.

⁴³ AF 2.2.2.

(e.g., where scientific research work is funded by non-profits but engineering is funded by private industry)?⁴⁴ Regardless of the answers to these questions, it is likely that the ExOIS field trials, which will be funded through grants from philanthropic organizations, private donations, and federal government grants, would meet this requirement.

- **Peer review:** The Assessment Framework indicates that the proposed activity should “be subject to scientific peer review at appropriate stages in the assessment process.”⁴⁵ The Assessment Framework does not clarify the specifics of when or how the peer review is to be conducted, however it mandates that the peer review methodology should be stated and the results should be made publicly available.⁴⁶ The work of the ExOIS Research Consortium is subject to peer review. The Consortium has, for example, published articles detailing the plans for its field trials in peer reviewed journals and is committed to making the results of the trials available in similar publications.⁴⁷
- **Publication:** Under the Assessment Framework, all results of the proposed research should be published in “peer reviewed scientific publications and include a plan in the proposal to make the data and outcomes publicly available in a specified time-frame.”⁴⁸ As the ExOIS Research Consortium has committed to an open data policy, as evidenced in the recent article in *Dialogues on Climate Change*, it should satisfy the publication requirements of the Initial Assessment.⁴⁹

If a proposed activity satisfies the Initial Assessment, it will then be subject to an Environmental Assessment. Upon completion of the Initial Assessment, the Secretariat of the LC and LP is to be informed.⁵⁰ Contracting Parties may also inform the Secretariat after receiving a proposal, prior to the completion of the Initial Assessment.⁵¹

3.2. Environmental Assessment

The Environmental Assessment follows the completion of the Initial Assessment, and requires details on six criteria delineated below. The information required for each of the criteria overlaps to varying degrees.

⁴⁴ In Section 4.1 below, we offer recommendations for clarifying the scope of “financial and/or economic gain,” and suggest alternative criteria that might be applied to evaluate proposed projects.

⁴⁵ AF 2.2.3.

⁴⁶ AF 2.2.3.

⁴⁷ *Supra* n.19.

⁴⁸ AF 2.2.4.

⁴⁹ *Supra* n.19.

⁵⁰ AF 1.7.

⁵¹ AF 1.7.

3.2.1. Problem Formulation

The Problem Formulation defines the bounds of the project. Proposals should include information about the project team and their affiliations, as well as any funding sources and financial interests.⁵² The proposal should also include the following, specific information about the project:⁵³

Information Required in the Assessment Framework	Information Available for the ExOIS Field Trial (taken from the recent article published in <i>Dialogues on Climate Change</i> ⁵⁴)
Proposed activity location.	Exact coordinates required. The article states the field trial will take place approximately 260 kilometers northwest of Ocean Station Papa (50°N 145°W).
Fertilized area (size).	30x30 to 50x50 km patch.
Amount of substance to be loaded and discharged, or the amount to be redistributed in the ocean.	10-50 tonnes of elemental iron.
A detailed description of the composition and form of substance(s) to be added or redistributed and the source of the substance(s).	Commercially available iron sulfate (FeSO ₄) dissolved in acidified seawater will be used.
The method, timing, and duration of both addition/redistribution of substance(s) and collection of data.	The iron will be deployed in acidified liquid form in the propeller wash of a ship, however further details are required on the timing and duration of the addition/redistribution of the iron. The use of the inert tracer SF ₅ CF ₃ will allow for near-real-time patch tracking from ships, at least during the first several weeks after discharge, and there are further measures proposed for tracking the patch evolution over several months.

⁵² AF 3.1.

⁵³ AF 1.7.

⁵⁴ *Supra* n.19.

The number, characteristics, and location of any structures to be located in the sea, if applicable – including temporary platforms.	Platforms, including recoverable autonomous vehicles, have been proposed for the field trial, however further details are required on the exact number, characteristics, and location.
Anticipated fate of added/redistributed substances including, where appropriate, uptake and settling.	Figures 4 and 5 of the ExOIS article clarify the expected response following the iron addition.
Anticipated changes in concentration of substances introduced/redistributed into the ocean.	Figures 4 and 5 of the ExOIS article clarify the expected changes in concentration following the iron addition.
The flag State(s) of the vessel(s) involved and the Port State(s) where the substance will be loaded aboard the vessel(s).	Details of the flag state of the vessel and the place where iron will be loaded onto it need to be clarified.
Plan for monitoring of and reporting on observed impacts on the marine environment.	The reporting plan includes a set of guiding principles that specifies that all planning and results will be shared in an open and transparent manner, and includes communication with the public and engagement with local communities, including Indigenous groups.

In addition to the information above, the project proponent must also provide a description of the activity-specific conceptual model and assessment endpoints. The conceptual model is comprised of an Impact Hypothesis, which is defined as a “concise statement of the expected consequences”⁵⁵ of the proposed project, and the identification of any gaps and uncertainties relative to the conceptual model that are to be addressed.⁵⁶ The project proponent must provide a statement of the expected consequences of the proposed project and any gaps or uncertainties in the analysis of those consequences. The assessment endpoints are defined as the “physical, biological or chemical attributes of the ecosystem to be protected, which may be adversely affected by the action of the experiment.”⁵⁷ The recent article published in *Dialogues on Climate Change* addresses this in part through the factors identified in the Go/No-Go criteria. The criteria specify, for example, that if biogeochemical impacts are detrimental or if the ExOIS Research Consortium cannot measure carbon dioxide drawdown or subsurface particulate organic carbon export with a high degree of confidence compared to prior

⁵⁵ AF 6.

⁵⁶ AF 2.3.1.

⁵⁷ AF 6.

studies, the field trial will be suspended.⁵⁸ These criteria reflect key attributes to be protected and the limits that cannot be crossed, however the permit application may require more explicitly defined assessment endpoints, as well as an explanation of any gaps and uncertainties in the conceptual model.

3.2.2. Site Selection and Description

This part of the Environmental Assessment concerns data required to evaluate “the physical, geological, chemical, and biological conditions” of the site proposed and its uncertainties.⁵⁹ Specific information on the proposed research site is required and the overall rationale for picking the proposed site should also be explained. The explanation should address: (1) the suitability of the site for testing the hypothesis; (2) the suitability of the site for minimizing undesirable effects; and (3) whether / how the site avoids proximity to areas of special concern and value.⁶⁰

The article published in *Dialogues on Climate Change* by the ExOIS Research Consortium explains how the proposed site – approximately 260 kilometers from Ocean Station Papa – would be impacted by the project.⁶¹ However a clearer rationale for choosing that site, which addresses the three criteria above, should be provided. Other sites that were considered but not selected should also be identified. The Assessment Framework states that potential sites should be ranked in order of priority as part of the Environmental Assessment.⁶²

The Assessment Framework further requests the following information about the proposed site:⁶³

- exact coordinates of the Proposed Region within which the site(s) will be selected;
- extent of the Region of Potential Impact;
- physical characteristics of the Proposed Region and Region of Potential Impact, including details of the water column (such as depth of water and temperature and salinity distributions), details of the sediment and seabed considerations, transport and mixing considerations, and meteorology, insofar as relevant to installed structures or dispersal systems;
- chemical characteristics of the region, including dissolved oxygen, composition and concentration of macro-nutrients, pH, alkalinity, contaminants and particulate loading and flux;

⁵⁸ *Supra* n.19.

⁵⁹ AF 3.2.1.

⁶⁰ AF 3.2.2.

⁶¹ *Supra* n.19.

⁶² AF 3.2.3.

⁶³ AF 3.2.

- biological and ecological characteristics, including the presence of benthic species and habitats (particularly of vulnerable ecosystems and protected species), species in the water column, and economically important species; and
- other considerations, such as proximity to other uses of the sea like navigation, fishing and traditional uses of the sea.

Details have been provided on some of the chemical characteristics of the site, such as dissolved oxygen and the pH from prior field trials near Ocean Station Papa.⁶⁴ While the ExOIS article highlights the importance of the rest of the information required, such as the impact to benthic species or the need to engage with communities who utilize that area of the sea, much of this information has not been made publicly available for the ExOIS field trials.

3.2.3. Exposure Assessment

The Exposure Assessment focuses on “the movement and fate of added substances within the marine environment” and any associated uncertainties. Key considerations are listed below:⁶⁵

Information Required in the Assessment Framework	Information Available for the ExOIS Project (taken from the recent article published in Dialogues on Climate Change ⁶⁶)
Mode of application	As stated in Section 3.2.1 above, details have been provided on the mode of delivery. More details are required on hazards due to ship operations and hazards if the substance reaches an unintended area.
Chemical characterization of the substance to be added (including tracers), which requires details of the chemical composition of the substance and any hazardous properties, including contaminants and impurities	Details have been provided on the chemical characterization of the iron and tracers, however further information is required on the hazardous properties, including the potential contaminants and impurities.
Physical characterization	Details are provided on the form, depth, and rate of addition of the materials in the water column,

⁶⁴ *Supra* n.19.

⁶⁵ AF 3.3.3.

⁶⁶ *Supra* n.19.

	duration, and other impacts to the physical environment.
Biological characterization, including details on the intended and unintended transport of organisms	Information on biological characterization have been provided in the discussion of Priority 7 and the use of models, but more specific details are required on the biological characterization of the area where the substances will be added, including on the impact of the substances to organisms there.
Methodology used to estimate exposure processes, including movement of all added substances and the sensitivity of the exposure to uncertainties and assumptions – This includes physical processes (e.g. currents, dispersion), chemical processes (e.g. decomposition, transformation) and biological processes (e.g. bio-accumulation, bio-magnification).	Figures 4 and 5, when paired with the details on the inert tracer and the sampling array, provide information on the exposure processes, including the methodology to be used from the physical-biogeochemical models. However, further details are required on assumptions and uncertainties, including specific information on physical, chemical and biological processes.
Other considerations - This requires detailing potential unintended impacts of the delivery method, as well as conflicts of the delivery method with other uses of the sea	Further information required on conflicts with existing uses of the sea and unintended impacts of delivery.

3.2.4. Effects Assessment

The Effects Assessment evaluates the short and long-term effects of the proposed project.⁶⁷ When describing the possible effects, the following information should be provided:⁶⁸

- Changes to marine ecosystem structures and dynamics, including sensitivity of species and habitats within and outside the fertilized area. These details involve biogeochemical changes (e.g., pH, oxygen), organism responses (e.g., population), ecosystem considerations (e.g., community composition, biodiversity, human health considerations, food-web interactions) and biogeochemical fluxes (e.g., trace elements, particulate carbon).

⁶⁷ AF 3.4.1.

⁶⁸ AF 3.4.2.

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- Potential adverse effects, such as hypoxia, acidification, HABs, turbidity, changes in sediment and downstream effects.
 - Methodologies, which should highlight uncertainties such as limited information available about experimental baseline conditions, natural variability within the risk assessment baselines and longevity of the response.

The recently published ExOIS article provides models on biogeochemical changes, specifically discussing changes in pH and dissolved oxygen concentrations.⁶⁹ Harmful algal blooms are highlighted as potential risks,⁷⁰ but further information is required on all of the questions, including more details on potential impacts to the marine ecosystem (particularly on organism and ecosystem considerations), other potential adverse effects (changes in sediment, hypoxia, and turbidity), and methodologies for risk assessment.

3.2.5. Risk Characterization

The Risk Characterization integrates the information from the Effects Assessment and Exposure Assessment to provide an estimate of the likelihood for adverse impacts and the magnitude of those impacts (i.e., risk is a function of magnitude of an adverse impact and its likelihood).⁷¹ Risk characterization is to be site-specific, and risks are to be characterized in terms of the assessment endpoints identified in the Problem Assessment (described above).⁷² The recently published ExOIS article provides limited information on risks, and subsequent permit applications would require additional information.

Risks can be characterized as physical, chemical, or biological.⁷³ Physical risks include any adverse impacts of platforms, and changes in the vertical distribution of heat from phytoplankton blooms.⁷⁴ Chemical risks include adverse effects from changes in pH, generation of climate-active gases like methane and changes in dissolved oxygen concentrations in the water.⁷⁵ Biological risks include adverse effects of toxins produced by harmful algal blooms and changes to the nutrient composition of seawater.⁷⁶ Risks should also take into account other

⁶⁹ *Supra* n.19.

⁷⁰ *Supra* n.19.

⁷¹ AF 3.5.1.

⁷² Assessment endpoints are defined as the “physical, biological or chemical attributes of the ecosystem to be protected, which may be adversely affected by the action of the experiment.” AF 6.

⁷³ AF 3.5.2.

⁷⁴ AF 3.5.2.1.

⁷⁵ AF 3.5.2.2.

⁷⁶ AF 3.5.2.3.

legitimate uses of the water, and whether the project would have an adverse impact on those uses, as well as whether any cumulative impacts would occur due to those uses.⁷⁷

To better characterize the risks, the project proponent must provide a baseline, or a description of the pre-existing state of the ecosystem before the project is undertaken, as part of the Site Assessment. For the baseline, information can be drawn from literature reviews, existing data from other activities, and targeted surveys.⁷⁸ Information provided from the Exposure and Effects Assessment, as well as previous field observations and modeling results, provide evidence for each conclusion about how the proposed OIF activity could influence the assessment endpoints.⁷⁹

When estimating the magnitude of effects, the project proponent must consider the temporal and spatial scale of the effects.⁸⁰ In general, the longer the duration of the effect, the larger the area over which the effects are manifested, and the greater the number of effects identified, the greater the overall risk of the project.⁸¹ Any uncertainties associated with the risks must also be disclosed.⁸² The project proponent is to provide a conventional risk assessment e.g. using a matrix (see Figure 2 below), and other factors contributing to its assessment of the magnitude of risk.⁸³

⁷⁷ AF 3.5.2.4 – AF 3.5.2.5.

⁷⁸ AF 3.5.7.

⁷⁹ AF 3.5.10.

⁸⁰ AF 3.5.9.

⁸¹ *Id.*

⁸² AF 3.5.10.

⁸³ AF 3.5.11.

Increasing acceptability ↘		Consequences			
		Severe	Moderate	Mild	Negligible
Probability					
High	High	High	Medium/Low	Very low	
Medium	High	Medium	Low	Very low	
Low	High/Medium	Medium/Low	Low	Very low	
Negligible	High/Medium/Low	Medium/Low	Low	Very low	

Figure 2: Risk Assessment Matrix⁸⁴

The ExOIS article does point out the potential for some risks, including site-specific risks, when discussing ecological risks such as harmful algal blooms.⁸⁵ However the magnitude and probability of those risks materializing should be addressed in greater detail in the permit application. Other physical and chemical risks, and the potential consequences of biological risks, have not been identified and requires further analysis.

3.2.6. Risk Management

The Risk Management part of the assessment focuses on how the risks identified at the Risk Characterization stage will be managed. The overarching goal is to ensure that, as far as practicable, “environmental risks are minimized and the scientific benefits maximized and that a precautionary approach is followed.”⁸⁶ The Assessment Framework indicates that risks may be managed through strategies such as temporal restrictions (e.g., discharges only occur during certain oceanographic conditions), spatial restrictions (e.g., discharges do not

⁸⁴ AF, Figure 3, p.17.

⁸⁵ *Supra* n. 19.

⁸⁶ AF 3.6.1.

occur in proximity to areas of special concern) or delivery restrictions (e.g. avoiding discharges of certain substances).⁸⁷ The Assessment Framework states that the project proponent should engage in contingency planning so that it is able to quickly respond if the Impact Hypothesis is found to be incorrect.⁸⁸ It further provides that, when developing risk management strategies and contingency plans, the project proponent should consult with countries that may be impacted to ensure that other activities in the proposed site are considered.⁸⁹

Also, as part of the risk management process, a monitoring plan should be developed and implemented to ensure that any requirements imposed on the project are complied with, and appropriate measures are put in place to protect the environment and human health.⁹⁰ The ExOIS Report does not address risk management, and a permit application will require a clear risk management plan, addressing issues of monitoring and management strategies.

4. GAPS AND RECOMMENDATIONS

The Assessment Framework offers a useful guide for determining whether an OIF project involves legitimate scientific research and for evaluating the environmental risks it poses. There is, however, room for improvement. Specifically, three key aspects of the Assessment Framework would benefit clarification and/or revision: (1) the requirement that there be no “financial and/or economic gain” from research; (2) the consideration of the environmental risks of OIF research alongside potential benefits; and (3) community engagement.

4.1. Financial and/or Economic Gain

The Assessment Framework states that “[t]here should not be any financial and/or economic gain arising directly from the experiment or its outcomes.”⁹¹ This could impede privately-funded research, which may be important to advance understanding of marine CDR, particularly while government support remains limited.⁹²

The term “financial and/or economic gain” is not defined in the Assessment Framework and there is significant uncertainty as to what it was intended to capture. Does it encompass any project that receives private sector

⁸⁷ AF 3.6.4.

⁸⁸ AF 3.6.5.

⁸⁹ AF 3.6.3.

⁹⁰ AF 3.6.6.

⁹¹ AF 2.2.2.

⁹² Brad Ack, David Koweek & Nikhil Neelakantan, *Advancing Research and Development of Marine Carbon Dioxide Removal: Ocean Visions, Running Tide, and the Role of Start-Ups*, OCEAN VISIONS, <https://oceanvisions.org/mcdr-startups/>.

funding? Is it limited to only projects that sell carbon credits? What if, as noted above, the sale of credits is used to cover research costs but there is no profit? A clearer definition of what constitutes “financial and/or economic gain” is needed to guide countries in determining whether proposed projects should be considered legitimate scientific research.

Alternatively, the requirement that there be no economic or financial gain from projects could be eliminated altogether. Other criteria could, instead, be used to differentiate research from deployment. For example, the Assessment Framework could adopt stricter data disclosure requirements to ensure projects remain research-focused, such as mandating open access to all research and findings. Size thresholds could also be established for research projects. This approach has been used in other contexts. For example, the European Union Directive on the Geological Storage of Carbon Dioxide defines research projects as those “with a total intended storage [of carbon dioxide] below 100 kilotonnes.”⁹³ In the context of OIF projects, the threshold could be similarly set based on the anticipated amount of carbon dioxide removed, the amount of iron dispersed, the area of ocean over which the dispersal occurs, or some other criteria. Different thresholds could be established for different phases of research so as to enable the scale-up of projects over time as knowledge of environmental and other impacts increases.

4.2. Considering the Benefits of OIF

In the 2008 Resolution, the Contracting Parties to the LC and LP concluded that “knowledge on the effectiveness and potential environmental impacts of ocean fertilization is currently insufficient to justify activities other than legitimate scientific research.”⁹⁴ The Assessment Framework was developed to assist parties in evaluating proposed research projects. As explained in Part 3 above, much of the Assessment Framework is focused on identifying and developing strategies to manage potential environmental risks from OIF research. This is appropriate; environmental risks require careful scrutiny, but so too do other project impacts, including potential positive impacts. Currently, the Assessment Framework does not provide for consideration of potential climate and other benefits of OIF projects, including their ability to lessen harm to the marine environment from climate change.

In a recent meeting, the Contracting Parties to the LC and LP recognized the need to consider potential benefits of marine CDR activities, including their climate change potential, alongside risks.⁹⁵ Consistent with that approach, the Assessment Framework should provide for a more holistic review of OIF projects that considers

⁹³ Directive 2009/31/EC, 23 April 2009.

⁹⁴ *Supra* n.12, preamble.

⁹⁵ Report of the Forty-Fifth Consultative Meeting of Contracting Parties to the London Convention, LC 45/17, 5.5 (Oct. 30, 2023); Report of the Forty-Sixth Consultative Meeting of Contracting Parties to the London Convention, LC 46/17, 5.7 (Nov. 22, 2024).

not only the consequences of OIF, but also the consequences of failing to address climate change. This aligns with other international commitments, such as the UN Framework Convention on Climate Change (UNFCCC), which states that parties should take “measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects.”⁹⁶

The Assessment Framework could thus be amended to balance potential adverse environmental effects against potential benefits, including climate mitigation and co-benefits such as reduced acidity. This may also encourage faster processing of permits, recognizing that reducing delays is essential to prevent the ongoing harms of climate change.

4.3. Community Engagement

The Assessment Framework does not require robust community engagement as part of the project development process. The Framework includes only limited requirements to review existing uses of the ocean area where a project will take place, such as traditional or aesthetic uses, but does not expressly require consultation with existing users. Moreover, the Framework says nothing about how competing interests should be resolved or managed. Further, the Framework makes no mention of how the project proponent is intended to engage with coastal communities or others who may have an interest in the research.

The Assessment Framework should incorporate more specific requirements for project proponents to identify and engage with potentially affected and/or interested groups. The recently adopted 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 Jurisdiction (BBNJ) could provide a starting point for developing such requirements. The BBNJ Agreement provides for clear prior consultations, and details how the consultations are to occur.⁹⁷

The Assessment Framework could be amended to require early engagement (e.g. 12-18 months before the pilot operations) and could require collaboration with local Indigenous communities, NGOs, universities, and others. By designing a robust participatory process that is attentive to local expectations and concerns beyond the scientific qualities of the experiment, the Framework would allow for more local involvement in the decision-making process, which should ultimately improve the design and execution of projects.⁹⁸ It is also important for

⁹⁶ United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107, Art. 3(3).

⁹⁷ 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 Jurisdiction, UNGAOR, Further resumed 5th Sess, UN Doc A/CONF.232/2023/4 (19 June 2023) [hereinafter “BBNJ”].

⁹⁸ Javier Lezaun, *Hugging the Shore: Tackling Marine Carbon Dioxide Removal as a Local Governance Problem*, FRONTIERS IN CLIMATE (2021).

equity reasons; it would be inequitable for national or international expert bodies to solely determine the validity of a project without involving local participation, given that the effects of marine CDR are often felt locally.

Engagement, however, should not stop at the project planning and scoping phase. As the project is ongoing, monitoring and decision-making regarding project changes must be inclusive and communicative.⁹⁹ The Framework could allow for greater knowledge sharing, through shared knowledge ownership and integration of traditional knowledge and practices where applicable.¹⁰⁰ Research can be co-designed and co-developed, thereby allowing for more targeted research efforts.¹⁰¹ Further, as the BBNJ requires, there could be a clear system providing for fair and equitable sharing of benefits.¹⁰² Benefits from marine research could be shared in an equitable manner and contribute to the conservation and sustainable use of the marine biological diversity.¹⁰³ Finally, as the research concludes, the Framework should require the cleanup and removal of any infrastructure which may interfere with the use of the water, and further document and address any environmental harms caused by the research.¹⁰⁴

5. CONCLUSION

OIF remains a conceptually promising approach to carbon dioxide removal, but further research is needed to resolve uncertainties around effectiveness, ecological risk, and monitoring. Although the Parties to the LC and LP have sought to develop a framework for governing OIF research, the application of that framework to real-world experiments remains largely untested, leaving many open questions. The ExOIS project offers a useful case study of the scientific, procedural, and governance requirements a proposed field trial must satisfy to qualify as legitimate research, while also exposing limitations in the Assessment Framework that may impede such work. In doing so, the case study helps bridge the gap between science and regulation, clarifying applicable legal obligations and contributing to greater certainty in the international governance of OIF.

⁹⁹ A CODE OF CONDUCT FOR MARINE CARBON DIOXIDE REMOVAL RESEARCH, ASPEN INSTITUTE (2023), p.16, https://www.aspeninstitute.org/wp-content/uploads/2025/05/110223_Code-of-Conduct_FINAL2.pdf.

¹⁰⁰ *Id.*, p.17.

¹⁰¹ *Id.*, p.26.

¹⁰² BBNJ, art 7(d).

¹⁰³ BBNJ, art 7(k).

¹⁰⁴ *Supra* n.80, p. 38