THE LONDON PROTOCOL'S MARINE GEOENGINEERING REGIME: ACCOUNTABILITY GAPS IN OCEAN FERTILIZATION, OCEAN ALKALINITY ENHANCEMENT, AND MARINE CLOUD BRIGHTENING

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Abstract

Marine geoengineering is located in a challenging position between responses to climate change and the protection of oceans. This Article addresses the legal challenges posed by that position. The London Protocol is the only document that provides an explicit global legal framework for marine geoengineering, though its framework for accountability is incomplete and uneven. The Article uses a doctrinal approach to review treaty texts, International Maritime Organisation (IMO) resolutions and working documents, decisions of the Convention on Biological Diversity (CBD), and pertinent international case law. The Article finds that within the IMO a more established control framework has been created for ocean fertilization, though within this framework the legality is also dependent upon an undefined exception for legitimate scientific research and limited authorization and oversight. The accountability gap is more significant for ocean alkalinity enhancement and marine cloud brightening as these do not currently fall within the 2013 amendment of Annex 4. Regulation will remain the responsibility of a combination of general international law, working drafts, and precautionary principles. The Article states that the principles of due diligence, responsibility, and the transboundary principle are more easily derived from the law of the sea and environmental law rather than the London Protocol itself. The Article asserts that in order to address the accountability gap, the marine geoengineering legal framework must be strengthened with an emphasis on the right of the public to participate and on stronger enforcement mechanisms.

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Keywords: London Protocol; marine geoengineering; ocean fertilization; ocean alkalinity enhancement; marine cloud brightening

1.1 INTRODUCTION

The governance of marine geoengineering overlaps the urgency of climate change and the necessity to protect the oceans. The growing interest in sea-based carbon removal and in some cases solar radiation management has recently extended the role of the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (more commonly known as the London Protocol).[1] From its origins in treaty provisions on dumping, it has now developed into the only explicit global regulatory system on marine geoengineering - albeit a system that is fragmented, partly binding, and specific to the different marine geoengineering institutional methods.[2]

That tension creates the main research question of this Article. Ocean fertilization has been partially controlled through the 2008 resolution, the 2010 Assessment Framework and the 2013 amendment to the London Protocol. [3] In contrast, ocean alkalinity enhancement and marine cloud brightening remain beyond the (still) incomplete controlling framework, despite the International Maritime Organisation's continuous work on their definitions and assessment frameworks, in addition to the private and commercially driven projects which went on record in 2025.[4]

This Article utilizes a doctrinal approach based on texts of treaties, decisions, resolutions, official materials, and supporting publications, and asserts that the London Protocol has developed a lexicon of precaution regarding marine geoengineering, but has not built a framework for an accountability system. The most pertinent gaps include the lack of provisions on entry into force, the definition of legitimate scientific research, the accountability of private actors, the transparency of the assessment of the environmental impacts of marine geoengineering, and the lack of remedial pathways for dealing with ecological damage. These gaps are present in all three primary approaches, but are most pronounced with respect to ocean alkalinity enhancement and marine cloud brightening.[5]

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1 London Convention and Protocol, *available at:* https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx (last visited on June 13, 2026).

2 Catherine Redgwell, "Technological Change and the Law of the Sea: The Challenge of Marine Geoengineering", 74 *International and Comparative Law Quarterly* 11 (2025).

3 International Maritime Organisation, *"Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization"* (2008).

4 International Maritime Organisation, *"Resolution LP.4(8) Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities"* (2013).

5 David L. VanderZwaag and Abdul Hafez Mahamah, "International Governance of Marine Geoengineering: Sketchy Seascape, Foggy Future", 55 *Ocean Development and International Law* 624 (2024).

1.2 THE ARCHITECTURE OF THE LONDON PROTOCOL REGIME

To understand the accountability framework, it is first necessary to outline the structure of the London Protocol. The provisions of the London Protocol concerning marine geoengineering are best described as an addition to the broader law of the sea.[6]

1.2.1 From Dumping Control to Geoengineering Regulation

The London Protocol updated the outdated dumping convention by utilizing a precautionary principle and adopting a reverse list approach to dumping where dumping is considered prohibited unless dumping is specifically allowed. The legal structure is important because the marine geoengineering falls within the waste disposal, permitting, and environmental assessment frameworks.[7] As a result, the legal framework is paradoxical. It is robust regarding the prior control of placement at sea, yet is significantly weaker regarding the long-term governance of experimental technologies whose negative impacts are likely to remain unknown until ecological feedback and transboundary effects are known.

The marine geoengineering framework developed gradually. The 2008 Resolution placed ocean fertilization under the treaty and stated that other activities should not be permitted. The 2010 Assessment Framework provided a tool to evaluate research on a case-by-case basis, and the 2013 Amendment added Article 6 bis along with Annexes 4 and 5 to introduce a more formal control framework. However, this control framework is more aspirational because the Amendment has not entered into force, which has a significant impact on certainty, consistency, and the ability to enforce the framework.[8]

1.2.2 Entry into Force and the Ratification Deficit

In October 2025, the London Convention had 87 Parties, the London Protocol had 56 Parties, and 9 Parties had accepted the 2013 marine geoengineering amendment. As shown in Figure 1, there is a clear disparity between the number of Parties to the dumping regime and the number of Parties accepting the legally binding marine geoengineering amendment.[9] This disparity is significant because the majority of States still rely on resolutions and changing administrative practices, while a system intended to be science-based, global, transparent, and effective is on hold.

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6 Rosemary Rayfuse, Aline Jaeckel, *et.al. (eds.), Research Handbook on International Marine Environmental Law* 124 (Edward Elgar Publishing, Cheltenham, 2nd edn., 2023).

7 Donald R. Rothwell and Tim Stephens, *The International Law of the Sea* 316 (Hart Publishing, London, 3rd edn., 2023).

8 International Maritime Organisation, *"Resolution LP.4(8) Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities"* (2013).

9 International Maritime Organisation, *"47th Consultative Meeting of Contracting Parties to the London Convention and the 20th Meeting of Contracting Parties to the London Protocol"* (October, 2025).

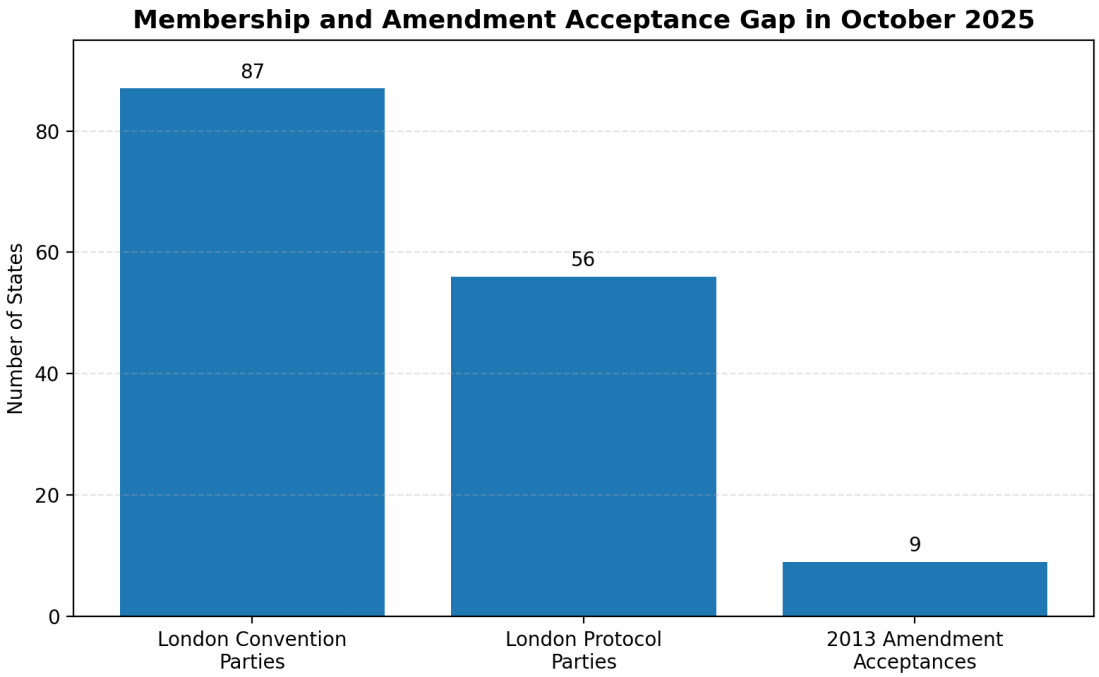

Figure 1. Membership and amendment acceptance gap in October 2025.[10]

As of October 2025, the London Convention will have 87 parties, the London Protocol 56, and the 2013 marine geoengineering amendment just 9 acceptances. The visual emphasizes that the participation for the marine geoengineering amendment is weak despite broad participation in the relevant treaties.

The problem of ratification creates an accountability issue that is more than just a technical issue. Where an amendment to a treaty has yet to come into force, the governance of risk is managed by soft law, expert assessments, and the discretion of the national regulators to enforce some degree of uniformity. For this reason, many regimes in this field have been characterized as experimental and iterative, as opposed to fully consolidated. While this characterization can be helpful, it is a poor description of the overall governance framework being created.[11] Experimental governance can promote learning, but it can also obfuscate legal accountability as decision-making becomes more opaque and more difficult to monitor.

1.2.3 Fragmentation Across Ocean Governance

The London Protocol exists within a broader normative framework provided by the United Nations Convention on the Law of the Sea, the Convention on Biological Diversity, and general principles of international environmental law. The United Nations Convention on the Law of the Sea establishes the baseline obligations to protect and preserve the marine environment and to mitigate and control marine pollution, as well as to engage in

[10] 47th Consultative Meeting of Contracting Parties to the London Convention and the 20th Meeting of Contracting Parties to the London Protocol (LC 47/LP 20), *available at:* https://www.imo.org/en/mediacentre/meetingsummaries/pages/lc-47-lp-20.aspx (last visited on June 13, 2026).

[11] Chiara Armeni, "Global Experimentalist Governance, International Law and Climate Change Technologies", 64 *International and Comparative Law Quarterly* 885 (2015).

cooperative activities to address the challenges and impacts of pollution which traverse international boundaries. The London Protocol provides more specificity to those obligations for certain marine interventions, while not negating the broader framework of the law of the sea.[12]

The Convention on Biological Diversity has built upon that broader precautionary context. Decision IX/16 C encouraged Parties to ensure that ocean fertilization should not take place in the absence of robust scientific justification and a global, transparent, and effective control mechanism. Decision X/33 extended the same precaution to the broader field of climate-related geoengineering.[1314] While none of these decisions replicate the London Protocol, they indicate that within the field of climate-related interventions the focus should be on ecological risk assessment, precaution, and the establishment of institutions, rather than a unilateral justification of climate necessity.

Fragmentation is thus not only an issue of overlapping institutions. It is a problem of distributed responsibility. When the relevant provisions are found in the London Protocol, the United Nations Convention on the Law of the Sea, decisions regarding biodiversity, and evolving forms of scientific advice, it becomes increasingly difficult to answer the questions: which institution is supposed to act, what are the obligatory legal procedures, and in which forum should the claims of damage or misconduct be addressed? This kind of dispersion may retain a degree of operational flexibility, and accountability system, however, is likely to suffer from a lack of transparency and reliability.[15]

1.3 OCEAN FERTILIZATION AND THE LIMITS OF THE RESEARCH EXCEPTION

Of all the components of the system, ocean fertilization is the most fully developed, and thus provides the best opportunity to evaluate the system. The ocean fertilization case illustrates that the precautionary approach can be articulated within the London Protocol, but it is also an example of the considerable amount of discretion that can be hidden within the exception for legitimate scientific research.[16]

1.3.1 Ocean Fertilization as the Only Listed Activity

Ocean fertilization is the sole example of marine geoengineering in Annex 4 of the 2013 amendment. This example is unusual in a couple of ways.[17] First, this example is the only one in this Article that has a specific framework for assessments. Second, this example has been the only one used in the effort to predict how marine

[12] Rosemary Rayfuse, Aline Jaeckel, *et.al. (eds.), Research Handbook on International Marine Environmental Law* 124 (Edward Elgar Publishing, Cheltenham, 2nd edn., 2023).
[13] Convention on Biological Diversity, "Decision IX/16 C: Ocean Fertilization" (2008).
[14] Convention on Biological Diversity, "Decision X/33: Biodiversity and Climate Change" (2010).
[15] Michael B. Gerrard and Tracy Hester (eds.), Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal 121 (Cambridge University Press, Cambridge, 1st edn., 2018).
[16] David Freestone and Rosemary Rayfuse, "Ocean Iron Fertilization and International Law", 364 *Marine Ecology Progress Series* 227 (2008).
[17] International Maritime Organisation, *"Resolution LP.4(8) Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities"* (2013).

geoengineering might evolve. In practice, the relative development of the regime does not eliminate uncertainty. It only changes the focus for decision-making from whether ocean fertilization is going to be regulated to how it is going to be regulated.

The uncertainty regarding ocean fertilization is due to a combination of nervousness of the unknown and caution that comes from dealing with regulatory frameworks. The concerns that were voiced in relation to large-scale ocean fertilization projects, some of which were associated with carbon markets, led the Parties to the London Convention and London Protocol to require that ocean fertilization not be used as a substitute for mitigation and to limit ocean fertilization to carefully controlled research. Understanding the historical context is essential to interpreting why ocean fertilization has become the classic example of the concern over the progression from science to commercialization, and from controlled experimentation to large-scale deployment.[18]

1.3.2 Legitimate Scientific Research and Permit Discretion

The construction "legitimate scientific research" serves as the main filter within the ocean fertilization regime, but is not self-applying. The 2010 Assessment Framework requires a case-by-case evaluation of the scientific rationale, the need, and the characterization of the environment and risks, as well as monitoring and reporting. Nonetheless, it affords considerable latitude to the State in deciding whether a proposal is legitimately research oriented, sufficiently regulated, and not in opposition to the purposes of the treaty. The challenge is not with the existence of discretion.[19] The challenge is that the regime provides limited public insight regarding the exercise of that discretion.

This is where the accountability gap becomes most pronounced. A proposal may technically adhere to permitting requirements, yet still create challenges when addressing issues of scale, reversibility, and commercial interests. Research on the episode of ocean fertilization in Canada illustrates how some domestic environmental legislation may have the ability to address such research, while also showcasing the inability of some of these frameworks to adequately deal with differentiating exploratory science and science with a private interest, lucrative technological development. Once that differentiation collapses, the legitimacy of the research exception erodes, and the necessity of independent oversight, public disclosure, and well-defined boundaries becomes greatly amplified.[20]

[18] Wil C.G. Burns and Andrew L. Strauss (eds.), Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks 109 (Cambridge University Press, Cambridge, 1st edn., 2013).

[19] International Maritime Organisation, *"Resolution LC-LP.2(2010) Assessment Framework for Scientific Research Involving Ocean Fertilization"* (2010).

[20] Neil Craik, Jason Blackstock, et.al., "Regulating Geoengineering Research through Domestic Environmental Protection Frameworks: Reflections on the Recent Canadian Ocean Fertilization Case", 7 *Carbon and Climate Law Review* 117 (2013).

1.3.3 Transparency, Monitoring, and Liability

The ocean fertilization regime has more detailed procedures than other techniques, but still lacks a comprehensive design for ex post accountability. While there are monitoring obligations, the treaty system lacks a dedicated marine geoengineering incident compliance body, a standing compensation system, or a detailed public registry to enable external oversight of proposed and granted research. It also lacks adequate detail regarding who is obliged to ensure compliance and how when post-authorization monitoring demonstrates ecological changes beyond the expected baseline. Essential oversight therefore remains nationally mediated and unevenly.[21]

This is significant because ocean fertilization can have diffuse ecological impacts which are virtually untraceable to a specific event, actor and time. The relevant literature has recognized for a long time the emerging uses of the high seas will require regulation not only because of the uncertain state of scientific knowledge but also because weak attribution, in the end, prohibits the assignment of responsibility for harmful acts. The way things stand, the absence of a specialized pathway to liability means accountability will have to be reconstructed from general international law and domestic permitting systems, and whatever evidence might remain after the ocean has intricately dispersed the impacts.[22]

1.4 OCEAN ALKALINITY ENHANCEMENT AND MARINE CLOUD BRIGHTENING BEYOND ANNEX 4

Ocean fertilization is the least informative of the three techniques for understanding outer limits of the regime. Ocean alkalinity enhancement and marine cloud brightening pose the outer limits of the regime much more clearly. All three techniques are at the forefront of scientific and policy workshops at the moment. However, all three lack a specific binding legal framework. Therefore, a framework for their governance will need to rely on the evolving positions of various institutions and general principles of law.[23]

1.4.1 Ocean Alkalinity Enhancement and Regulatory Misfit

The definition of ocean alkalinity enhancement presented by the International Maritime Organisation includes the addition of minerals such as olivine to seawater to increase the capacity of the ocean to absorb carbon dioxide. Despite the framing of this technique as marine carbon dioxide removal, an interesting regulatory question arises that is not answered in the best way by the dumping framework.[24] At what point does the intentional modification

[21] Jung-Eun Kim, "Implications of Current Developments in International Liability for the Practice of Marine Geo-Engineering Activities", 4 *Asian Journal of International Law* 235 (2014).
[22] Wil C.G. Burns and Andrew L. Strauss (eds.), Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks 109 (Cambridge University Press, Cambridge, 1st edn., 2013).
[23] The Royal Society, "Geoengineering the Climate: Science, Governance and Uncertainty" 57 (2009).
[24] Marine Geoengineering, *available at:* https://www.imo.org/en/OurWork/Environment/Pages/geoengineering-Default.aspx (last visited on June 12, 2026).

of the chemistry of the seawater become analogous to the placement of substances that are considered to be a form of disposal, and at what point does it become a beneficial intervention to the ecosystem and not pollution?

Legal complexity is intensified when scale and time issues are considered. Small coastal trials, offshore pilots, and large-scale interventions may be similar in design, but can be very different in terms of ecological impact, reversibility, requirements for transboundary dialogue, and so on. Scientific and policy reports state that there is a significant level of uncertainty regarding local chemistry, the response of ecosystems, and the long-term sustainability of monitoring. Legally, this uncertainty provides a strong argument for the need to impose much more stringent prior assessments and independent reviews.[25] However, the existing regime is still without a final binding instrument that is designed specifically for the chemical and spatial characteristics of the technique in question.

1.4.2 Marine Cloud Brightening and the Dumping Paradigm

The concept of marine cloud brightening is more complicated. According to the International Maritime Organisation, this refers to the potential addition of sea salt or other reflective particles to a marine cloud to increase reflectivity and decrease the amount of energy absorbed by the ocean. Marine cloud brightening is different from ocean fertilization and ocean alkalinity enhancement.[26] Concepts related to marine cloud brightening are a little more challenging to link to the marine environment since the immediate site of intervention is in the atmosphere. Relying on concepts relating to the disposal of materials or dumping at sea will be problematic.

It is apparent from more recent literature that the marine cloud brightening example will test the boundaries of the London Protocol from marine pollution to climate intervention. This will likely only be partially successful. The Protocol will have the ability to express precaution and mandate legal consideration of potentially harmful marine effects. However, the Protocol will struggle to address issues related to the attribution of effects, spatial jurisdiction, emergency suspension, and long-range climate feedbacks.[27] This is especially the case when the primary impact of the intervention cannot be considered marine dumping. The definitional gap also contributes to the accountability gap.

Considering field testing, that deficit becomes more pronounced. The proposals for Marine cloud brightening may be intended for regional scale, but will have transboundary impacts, especially if they alter patterns of precipitation, if they change cloud persistence, or if they change weather dynamics at the coast. The governance of research reports on solar geoengineering state that with the design of research, governance must also evolve

[25] The Royal Society, "Geoengineering the Climate: Science, Governance and Uncertainty" 57 (2009).
[26] Marine Geoengineering, *available at:* https://www.imo.org/en/OurWork/Environment/Pages/geoengineering-Default.aspx (last visited on June 12, 2026).
[27] Jesse L. Reynolds, *The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene* 154 (Cambridge University Press, Cambridge, 1st edn., 2019).

because of the unknowns of the atmospheric feedbacks, the unknowns of the reversibility, and the unknowns of the public acceptability which cannot be postponed to the time when the project is going to be implemented. The current London Protocol does not reflect those concerns in a marine specific authorization model.[28]

1.4.3 The Consequences of Remaining Unlisted

The governing bodies have identified marine cloud brightening and ocean alkalinity enhancement as priority methods that need to be defined and analysed legally, and they will continue this work until 2025 and also during the 2026 intersessional period. The current status of the marine cloud brightening and ocean alkalinity enhancement techniques is shown in Figure 2.[29] Only one technique is specifically mentioned in Annex 4, while the other two remain in an unresolved status of further analysis. This is not a trivial drafting issue. It is a distinction between a technique for which a model of assessment is accepted, and techniques that require a model of assessment and are therefore in a draft state.

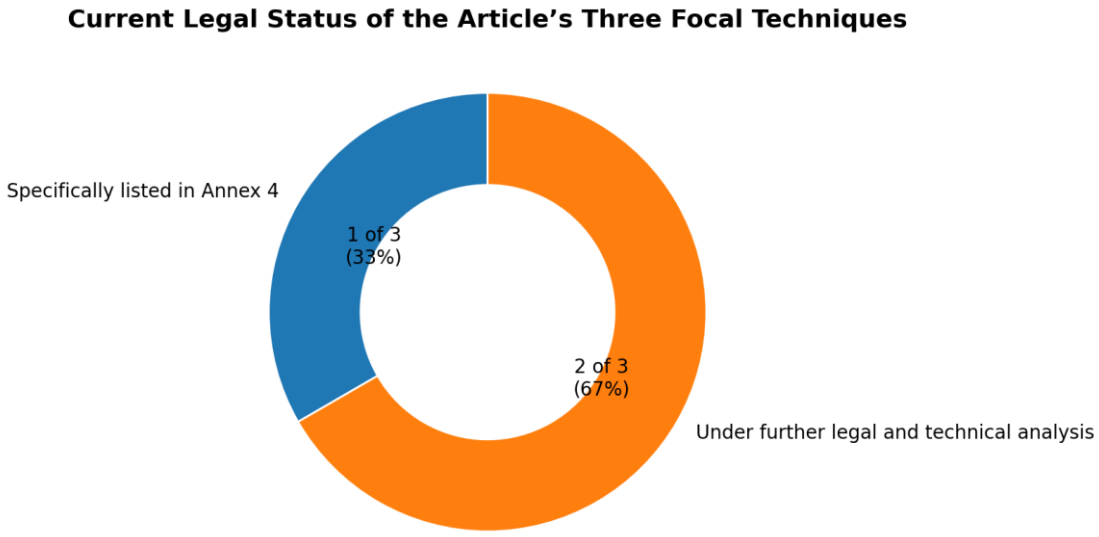

Figure 2. Current legal status of the Article's three focal techniques.[30]

Of the three techniques studied, only ocean fertilization appears in Annex 4 in the 2013 amendment. Ocean alkalinity enhancement and marine cloud brightening are still undergoing legal and technical analysis, creating a more uncertain and ambiguous framework for responsibility for these techniques.

[28] National Academies of Sciences, Engineering, and Medicine, *"Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance"* 141 (2021).

[29] International Maritime Organisation, *"46th Consultative Meeting of Contracting Parties to the London Convention and the 19th Meeting of Contracting Parties to the London Protocol"* (November, 2024).

[30] Marine Geoengineering, *available at:* https://www.imo.org/en/mediacentre/hottopics/pages/marine-geoengineering.aspx (last visited on June 13, 2026); 46th Consultative Meeting of Contracting Parties to the London Convention and the 19th Meeting of Contracting Parties to the London Protocol (LC 46/LP 19), available at: https://www.imo.org/en/mediacentre/meetingsummaries/pages/lc-46-lp-19.aspx (last visited on June 13, 2026).

The main effect of being unlisted is that control becomes more arbitrary and disparate. National governing bodies, researchers, sponsors, and impacted coastal communities will have to deduce the legal requirements from the broad goals of the treaty, and the assessment statements and drafts in process, as opposed to the final and formal governing frameworks. Recent studies have noted that the international governance of marine geoengineering is rudimentary at best, especially with these two techniques. To the extent the governance of a technique moves away from the formal listing and permitting, the greater the risk that precaution becomes merely a verbal expression, rather than something that is operational.[31]

1.5 ACCOUNTABILITY, DUE DILIGENCE, AND INTERNATIONAL RESPONSIBILITY

In the absence of a dedicated treaty framework, accountability for marine geoengineering will have to be established through the provisions of general international law. This will involve concepts such as due diligence, transboundary environmental impact assessments (EIA), prior notification and consultation, the control of private actors, and the provision of reparation for proven ecological harm.[32]

1.5.1 Environmental Impact Assessment and Prior Notification

The most relevant contemporary case is the *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*[33] case, in which the International Court of Justice incorporated the concept of EIA into the provisions of general international law when there is the potential for significant transboundary harm. The application of this principle to marine geoengineering goes beyond the mere preparation of documentation. It connects legality to the substance of the process, requiring prior scientific assessment and the consideration of downstream ecological impacts. A regime that allows the performance of experiments without adequate consideration of transboundary impacts will ultimately fail not only its own precautionary measures, but also its obligations to the broader international community.

The London Protocol is explicitly implicated. Ocean fertilization and ocean alkalinity enhancement and marine cloud brightening present numerous situations that would most likely produce cross-border impacts of a potential ecological nature due to changes in biogeochemical systems, circulation, and climate responsiveness. The Ocean Fertilization Assessment Framework of 2010 provides some indication in this regard as it incorporates consultation, notification, and reporting as part of the assessment process. However, these obligations are far less defined for the other techniques, which, consequently, will necessitate the development of operational standards

[31] David L. VanderZwaag and Abdul Hafez Mahamah, "International Governance of Marine Geoengineering: Sketchy Seascape, Foggy Future", 55 *Ocean Development and International Law* 624 (2024).
[32] Donald R. Rothwell and Tim Stephens, *The International Law of the Sea* 316 (Hart Publishing, London, 3rd edn., 2023).
[33] [2010] I.C.J. Rep. 14.

within the context of the overarching principles of transboundary environmental impacts rather than within the context of a complete marine geoengineering framework.[34]

1.5.2 Private Actors, Sponsor State Logic, and Remedial Deficits

The involvement of private entities and the commercialization of activities create additional challenges for ensuring accountability. The International Maritime Organisation's 2025 meeting summary explicitly referenced the increasing number of marine geoengineering activities, many of which are undertaken by private or commercial enterprises and which are likely to have international ramifications due to their potentially harmful effects. Once private entities are involved in the testing, funding, or advocacy of marine interventions, effective governance goes beyond the permission of States.[35] It encompasses the authority to manage and verify compliance and respond when the terms of the grant of permission are no longer met.

The advisory opinion in *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area*[36] helps construct a stringent model of due diligence for State supervision of private actors carrying out hazardous functions. It involves precaution and an assessment of the impact on the environment, the application of best environmental practices, and provision of access to remedy and compensation. Even if marine geoengineering occurs outside the context of the treaty regulating seabed mining, the reasoning applies. Particularly when an activity has the potential to cause serious and largely irreversible damage to the marine environment, granting authorization and then standing by is inadequate.

Remedial accountability, however, is still in its infancy. In the cases *Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v. Nicaragua) and Construction of a Road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica)*[37], the International Court of Justice associated compensation with unlawful acts of environmental degradation and affirmed that the destruction of an ecosystem is a basis for reparative obligations.[38] While there is no specific compensation provision in the London Protocol for marine geoengineering, claims would have to be pursued through general international law, domestic law, or mixed jurisdiction, all of which are problematic when the required conditions are difficult to determine and the injured environment is dispersed.

1.5.3 Jurisprudential Signals from the Climate and Oceans Docket

Other rulings further illustrate the same accountability trajectory. In *The South China Sea Arbitration (The Republic of the Philippines v. The People's Republic of China)*[39], the tribunal characterized serious harm to coral

[34] International Maritime Organisation, *"Resolution LC-LP.2(2010) Assessment Framework for Scientific Research Involving Ocean Fertilization"* (2010).
[35] International Maritime Organisation, *"47th Consultative Meeting of Contracting Parties to the London Convention and the 20th Meeting of Contracting Parties to the London Protocol"* (October, 2025).
[36] ITLOS Case No. 17, Advisory Opinion of 1 February 2011.
[37] [2015] I.C.J. Rep. 665.
[38] [2018] I.C.J. Rep. 15.
[39] PCA Case No. 2013-19, Award of 12 July 2016.

reef ecosystems as a significant violation of the obligation to protect and preserve the marine environment. Although the case does not involve geoengineering, it is instructive because it illustrates how law of the sea provisions can convert ecological harm to marine treaty obligations when sufficient marine scientific data are available.

In contrast, more recent climate change law advances the due diligence standard. The *Request for an Advisory Opinion Submitted by the Commission of Small Island States on Climate Change and International Law*[40] interprets the obligation to prevent, reduce, and control marine pollution as a demanding standard in the context of serious and irreversible harm. The use of that logic in consideration of marine geoengineering is that it places a greater obligation of care in the face of scientific uncertainty as opposed to providing a basis for regulatory inaction.

The International Court of Justice, in its advisory opinion on the *Obligations of States in Respect of Climate Change*[41], maintains that climate commitments must be understood holistically in the context of other disciplines of international law. The opinion also maintains that States must defensibly rationalize high-risk climate actions in the context of a legally defensible framework of prevention and cooperation. Together with other opinions, it maintains that any future framework of international law governing marine geoengineering will be assessed in terms of its rules and, equally importantly, the extent to which it ensures a commitment to prevention, cooperation, and restoration.

1.6 CONCLUSION

The marine geoengineering framework of the London Protocol has, at the very least, moved international law from the state of having nothing to say on the subject to having something to say, even if that is not yet fully formed. The main contribution of the Protocol is to demonstrate that the marine climate intervention field is not legally ungoverned and cannot be left to unilateral technological optimism.[42]

The regime's shortcoming is that precaution has outpaced accountability. Ocean fertilization is the most developed part of the regimen, but even there the legality is highly dependent on the interpretation of national authorities of legitimate scientific research, the degree of transparency they offer, and the quality and quantity of their monitoring of the projects after they have been authorized. The legal framework for ocean alkalinity enhancement and marine cloud brightening is even more underdeveloped, given that both methods are still outside a finalized binding instrument and, consequently, outside established method-specific permit criteria.[43]

[40] ITLOS Case No. 31, Advisory Opinion of 21 May 2024.
[41] I.C.J. General List No. 187, Advisory Opinion of 23 July 2025.
[42] Catherine Redgwell, "Technological Change and the Law of the Sea: The Challenge of Marine Geoengineering", 74 *International and Comparative Law Quarterly* 11 (2025).
[43] Jung-Eun Kim, "Implications of Current Developments in International Liability for the Practice of Marine Geo-Engineering Activities", 4 *Asian Journal of International Law* 235 (2014).

More fundamentally, the responsibility for harm resulting from marine geoengineering is still predominantly borne, as in other areas of the law of the sea and environmental law, rather than being assigned, as it should be, within a developed internal treaty system. Although legally applicable concepts, such as transboundary environmental impact assessment, due diligence, oversight of private entities, and compensation for environmental harm, are available, they have not yet been integrated into a marine geoengineering regulatory framework. The London Protocol will continue to be a necessary but incomplete framework of significant legal and institutional value, yet still characterized by substantive accountability gaps.[44]

A more articulate future framework will continue to incorporate governance experiments. Entering into force the 2013 amendment and the subsequent introduction of public authorization standards, independent oversight, full project registration, and more defined remedial rules would not eliminate all the challenges associated with ocean-based climate intervention. However, they would increase the credibility of the current regime by making its precautionary stance associated with enforceable commitments and tangible institutional accountability. That alignment is the baseline requirement for considering marine geoengineering as a legally manageable domain, rather than a collection of isolated projects largely controlled by administrative improvisation.[45]

1.7 SUGGESTIONS

The recommendations that follow primarily target the structural gaps and deficiencies related to authorization and accountability for marine geoengineering activities under the London Protocol. Some of the gaps and deficiencies include: oversight, transparency, and accountability. Also included are gaps and deficiencies related to the design of remedial systems and inter-institutional coordination as well as oversight and accountability.

1. Strengthen acceptance of the 2013 amendment: States Parties should first focus on outreach in support of the acceptance of the 2013 marine geoengineering amendment. The current geoengineering regime suffers from a lack of binding decisions on authorization and supervision. Consequently, it provides unstable expectations regarding responsibility and accountability.
2. Create a public authorization registry: The International Maritime Organisation and national authorities should create a public registry of marine geoengineering activities that is continuously updated to include proposed, approved, rejected, and completed activities. An open registry would enhance scrutiny of the science, minimize information asymmetry, and help prevent the progression of activities from research to offshore deployment.
3. Define legitimate scientific research more tightly: The current exception needs to be perfected with criteria in regard to scale, commercial involvement, anticipated climate impact, reversibility, data sharing, and

[44] Rosemary Rayfuse, Aline Jaeckel, *et.al. (eds.), Research Handbook on International Marine Environmental Law* 124 (Edward Elgar Publishing, Cheltenham, 2nd edn., 2023).

[45] International Maritime Organisation, *"47th Consultative Meeting of Contracting Parties to the London Convention and the 20th Meeting of Contracting Parties to the London Protocol"* (October, 2025).

absence of offset marketing. A more precise definition would also mitigate the danger that the research category would serve as a legal safe harbour for early deployment.

4. Require transboundary environmental impact assessment for all field trials: Any field experiment that would have a credible as yet undefined cross border ecological impact should automatically initiate a transboundary environmental impact assessment and a prior notification requirement. This would also hold true for unlisted techniques since the legal obligation stems from the risk and not from the administrative convenience.
5. Institutionalize independent scientific review: The responsibilities for reviewing a project should not be assigned solely to the sponsoring or permitting State. Before project authorization, an independent expert panel associated with the roster of experts should evaluate methodology, baseline assumptions, monitoring design, and contingency planning.
6. Adopt technique specific monitoring protocols: Ocean fertilization, ocean alkalinity enhancement, and marine cloud brightening create different forms of risk and therefore require different logics of monitoring. Standardized protocols should describe baseline data, the duration of monitoring, the interval for reports, and thresholds that will trigger the stopping or redesigning of the project.
7. Clarify obligations relating to private actors: States ought to be mandated to show evidence of ongoing oversight of private sponsors, contractors, and research organisations for the duration of a project. Permit systems should incorporate auditing rights, access to data, financial assurance, and withdrawal mechanisms that can be enforced if terms of the project are violated.
8. Develop a marine geoengineering compensation pathway: The treaty system should establish a protocol for recording environmental harm, maintaining scientific evidence, and evaluating compensation when damage to the marine environment has been substantiated. A minimalistic claims system would enhance deterrence and lessen the existing reliance on unpredictable, post facto litigation.
9. Coordinate formally with biodiversity and ocean institutions: Future governance provisions should include intentional collaboration with the Convention on Biological Diversity, the Intergovernmental Oceanographic Commission, and pertinent law of the sea elements. Such collaboration would facilitate the harmonization of scientific standards, obstruct regulatory arbitrage between institutions, and diminish fragmentation.
10. Protect vulnerable and affected communities in decision making: Before field testing is undertaken, involvement of the small island developing States, coastal communities, and groups likely to be affected is warranted, rather than just in response to the issues that may emerge. Such involvement should be ongoing and include all phases of the project from agenda setting and review to monitoring and evaluation, to ensure that accountability is not the sole responsibility of the contracting States and experts.

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