TOWARDS EFFECTIVE GOVERNANCE OF MARINE GEOENGINEERING IN WEST AFRICA: ALIGNING WITH GLOBAL AND REGIONAL BEST PRACTICES

By

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DEDICATION

I dedicated this thesis to the cherished memory of my late father, Mr. Mahamah Sulemana Abagrey, upon whose shoulders I stand.

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Abstract

The impacts of climate change have compelled humanity to produce innovative ways of counteracting this phenomenon. Marine geoengineering technologies are regarded as an avenue to forestall climate change. However, these technologies pose a danger to the environment and threaten the survival of living organisms and humanity. The deployment of these technologies could exacerbate the adverse impacts that climate change has on the environment. Using doctrinal, legal history, and comparative legal analysis, this thesis studies how West Africa can ensure the effective governance of marine geoengineering activities in the subregion. The study examines the global and selected regional governance regimes and arrangements in place on marine geoengineering, to ascertain the best approaches to govern this technique.

List of Abbreviations Used

AGN - African Group of Negotiators

AMCEN - African Ministerial Conference on the Environment

AU - African Union

BECCS - Bioenergy with Carbon Capture and Storage

BTD - Brine Thermal Decomposition

CAHOSCC - Committee of African Heads of State and the Government on Climate Change

CBD - Convention on Biological Diversity

CDM - Clean Development Mechanism

CDR – Carbon Dioxide Removal

COP - Conference of Parties

CO_2 – Carbon dioxide

DCG - Density Current Generator

ECOWAS - Economic Community of West Africa

EEZ - Exclusive Economic Zone

EIA - Environmental Impact Assessment

EU - European Union

FRAM - Framework for Risk Assessment and Management of CO2 Streams in Geological Formations

HELCOM - Baltic Marine Environment Protection Commission

HNLC - High-Nutrient Low-Chlorophyll

IMO - International Maritime Organization

IPCC - Intergovernmental Panel on Climate Change

LBSA - Land-Based Sources and Activities

LC – London Convention

LICG - Legal Intersessional Correspondence Group

LP – London Protocol

MSSD - Mediterranean Strategy on Sustainable Development

MPa – MegaPascal

Mt C - Metric Tons of Carbon

NAS - National Academy of Science

NDC – Nationally Determined Contribution

OTEC – Ocean Thermal Energy Conversion

SBSTTA - Subsidiary Body on Scientific Technical and Technological Advice

SDG - Sustainable Development Goal

SRM – Solar Radiation Management

SRMGI - Solar Radiation Management Government Initiative

UK - United Kingdom

UN - United Nations

UNCLOS - United Nations Conventions on the Law of the Seas

UNEP - United Nations Environment Program

UNFCCC - United Nations Framework on Climate Change

UNGA - United Nations General Assembly

USA - United States of America

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CHAPTER ONE: INTRODUCTION

There is unambiguous evidence of the impacts of climate change on the marine environment and the living organisms in the ocean. In the case of marine organisms, they are affected in two ways - by the changes in the natural habitat and food supply and changes in ocean chemistry.[1] As the oceanic temperature gradually increases due to climate change and global warming, it is expected to decrease the population of phytoplankton, thereby affecting the nutrients available to living organisms in the ocean.[2] An increase in temperature in the ocean is likely to compel the migration of marine organisms based on the degree of temperature tolerance, with heat-tolerant species migrating northwards and those less tolerant species retreating.[3] Climate change causes rise in sea-level,[4] and this is because of warm water occupying a larger volume than an equal mass of colder water at the same pressure.[5] Also, there is sufficient evidence showing a decline in coral reef health because of current levels of ocean warming and acidification.[6]

The impacts of climate change are partly attributable to the ocean serving as a buffer against climate change and its impacts. The ocean has served as a buffer against climate change for many centuries.[7] According to the Intergovernmental Panel on Climate Change (IPCC), the ocean significantly reduces atmospheric carbon dioxide concentration and cools the

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[1] Maria Creary, "Impacts of Climate Change on Coral Reefs and the Marine Environment" (2013) 50:1 UN Chronicle 24-27 at 26.
[2] Ibid.
[3] Ibid.
[4] Geir Ottersen et al., *supra* note 4.
[5] Ibid.
[6] Jan McDonald et al., "Governing Geoengineering Research for the Great Barrier Reef" (2019) 19:7 Climate Policy 801-811.
[7] Geir Ottersen et al, *supra* note 4 at 11.

environment. Nevertheless, climate change keeps altering the ocean and cryosphere in diverse ways: a situation that is alarming for nature and humanity.[8]

Although the ocean naturally plays a crucial role in addressing climate change, humanity is devising strategies to facilitate and enhance the capacity of the ocean to store atmospheric carbon dioxide using a technique termed as geoengineering. Geoengineering is the deliberate manipulation of the planetary environment to address anthropogenic climate change on a large scale.[9] Over the years, several marine geoengineering techniques have been proposed to address climate change.[10] Nonetheless, the development of a governance regime, particularly at the regional level does not reflect the rate at which these marine geoengineering techniques evolve.

The concerns regarding the adverse impacts of marine geoengineering on the marine environment raise the need to govern these technologies effectively. At the global level, considerable progress has been chalked under a handful of multilateral environmental agreements to govern marine geoengineering.[11] The Contracting Parties to these multilateral environmental agreements have adopted resolutions and effected amendments to cater for the gap in effectively governing these activities.[12] Besides these global efforts, some regional seas programs have instituted mechanisms which promote the governance of marine geoengineering

[8] Intergovernmental Panel on Climate Change (IPCC), IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)] (Cambridge: Cambridge University Press, 2019) 755, online: https://www.ipcc.ch/site/assets/uploads/sites/3/2022/03/SROCC_FullReport_FINAL.pdf.
[9] The Royal Society, Geoengineering the Climate: Science, Governance, and Uncertainty (London: The Royal Society, 2019). Available at: https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2009/8693.pdf at 1.
[10] See Chapter Two for an elaborate discussion of the processes and impacts of some marine geoengineering techniques.
[11] See Chapter Three for a discussion of the global marine geoengineering governance regime.
[12] Ibid.

activities to some degree.[13] Presently, the West African sub-region is instituting mechanisms to govern these technologies.

West Africa is witnessing a growing interest in research and experiment of marine geoengineering, thus necessitating a pragmatic marine geoengineering governance framework in the region. The African Union has adopted an Action Plan which urges member States, including West African countries, to contribute to the research, development, and regulation of marine geoengineering at the global and regional levels.[14] In the sub-region, the overarching regional Convention[15] in operation plays a significant role in regu

lating activities deemed as pollution including pollution by dumping.[16] Yet, to ensure effective governance of marine geoengineering activities in the region, there is a need to tailor and streamline regulations to specifically address the research, experimentation, and deployment of these technologies in the region.

Against this backdrop that the thesis examines the governance regimes on marine geoengineering at the global and regional level, especially governance regimes in the Baltic Sea, Mediterranean Sea, and the North-East Atlantic Sea regions. Examining these regimes presents this thesis with a basis to examine and propose best practices and approaches in governing marine geoengineering at the global level and in West Africa.

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[13] See Chapter Four for a discussion on examining marine geoengineering governance in the Baltic, Mediterranean, and North-East Atlantic regions.

[14] African Union, "African Union Climate and Resilient Development Strategy and Action Plan (2022-2032)". Available at: https://www.tralac.org/documents/resources/african-union/4566-au-climate-change-and-resilient-development-strategy-and-action-plan-2022-2032/file.html. [AU Climate and Resilient Development Strategy and Action Plan].

[15] Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region and Protocol, 23 March 1981, ILM Vol. 20, p. 746-76 Art.1. [Abidjan Convention].

[16] See Chapter Five for an elaborate discussion of the role of the existing regional framework in governing marine geoengineering.

The layout of this thesis is in six Chapters. In addition to the above introduction, Chapter One of this thesis discusses the methodological approaches to conducting this research. The study applies three research methodologies in conducting this study. These methodological approaches are doctrinal, legal history, and comparative analysis research methodologies.

Chapter Two of the study discusses several marine geoengineering techniques. This Chapter explains the term "geoengineering" and the classification of geoengineering. There is a consensus across the literature that carbon dioxide removal (CDR) and solar radiation management (SRM) are the two main classifications of geoengineering. This Chapter explains CDR and SRM and lists examples of each. Additionally, this Chapter discusses the various marine geoengineering techniques and their potential environmental impacts. Furthermore, it discusses marine geoengineering techniques such as ocean fertilization, carbon storage methods in the ocean, artificial upwelling, artificial downwelling, ocean alkalinity, methane capture and destruction or degradation, increasing ocean reflectivity, marine cloud brightening, ocean thermal energy conversion (OTEC), and deep-water source cooling.

Chapter Three examines the global international regimes that govern marine geoengineering activities. This Chapter examines multilateral environmental agreements like the United Nations Conventions on the Law of the Seas (UNCLOS),[17] United Nations Framework on Climate Change (UNFCCC) regimes,[18] the Convention on Biological Diversity (CBD),[19] and

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[17] United Nations Convention on the Law of the Sea, 10 December 1982, 1833 UNTS 3 (entered into force 19 November 1994) [UNCLOS].

[18] United Nations Framework Convention on Climate Change, 9 May 1992 1771 UNTS 107 (entered into force 21 March 1994) [UNFCCC]; Kyoto Protocol to the United Nations Framework Convention on Climate Change, 11 December 1997, 2303 UNTS 162 (entered into force 16 February 2005) [Kyoto Protocol]; Paris Agreement to the United Nations Framework Convention on Climate Change, 12 December 2015, treaty Reg No 54113 (entered into force 4 November 2016) [Paris Agreement].

[19] Convention on Biological Diversity, 5 June 1992, 1760 U.N.T.S 79 (entered into force on 29 December 1993), Art. 2. Available at: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-8&chapter=27. [Convention on Biological Diversity].

the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter (London Convention)[20] and Protocol to the Convention on the Protection of Marine Pollution by Dumping of Wastes and Other Matter (London Protocol).[21]

The discussion under Chapter Three outlines the governance of these techniques using broader environmental obligations, resolutions, or amendments to existing multilateral environmental agreements. International instruments such as UNCLOS and the UNFCCC regimes establish general obligations which apply to marine geoengineering. In the case of CBD and the London Convention and London Protocol, the resolution adopted by Contracting Parties govern these activities, and in some instances, these resolutions have led to the amendment of the London Protocol.

Chapter Four discusses the regional marine geoengineering governance framework under the United Nations Environment Program (UNEP) regional seas program. In this context, three regional sea programs are of interest: the Baltic Sea, the Mediterranean Sea, and the North-East Atlantic Sea region. Under this Chapter, the operative regional conventions, action plans, and soft laws in each region is examined based on marine geoengineering. Besides these interventions, the study examines analogous regimes on carbon sequestration in the ocean enacted by the European Union (EU) operating in the Baltics and Mediterranean Sea regions.

Chapter Five discusses marine geoengineering governance in West Africa. It highlights geoengineering activities taking place in West Africa and examines the existing regional regimes on marine geoengineering in the region. The existing regional regimes to be discussed in this Chapter are the Convention for Cooperation in the Protection, Management, and Development of

[20] Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, 29 December 1972, 1046 UNTS 120 (entered into force 23 June 1977) [London Convention].
[21] Protocol to the Convention on the Protection of Marine Pollution by Dumping of Wastes and Other Matter (adopted 7 November 1996; entered into force 24 March 2006) [London Protocol].

the Marine and Coastal Environment of the Atlantic Coast of the West and Central Africa Region (Abidjan Convention) and its Protocols, and the Articles of Association for the Establishment of an Economic Community of West Africa (ECOWAS Treaty).[22] The obligations to prevent and protect the environment imposed by these regimes apply to marine geoengineering activities in the region. Additionally, the Chapter examines the role of the African Union (AU) in promoting the governance of these technologies and the contributions of the Action Plan adopted by the AU in ensuring the establishment of a robust regional regime.

Chapter Six is the conclusion chapter of the thesis. It presents the conclusions and future directions from the previous chapters' discussions. Based on the discussions in Chapters One to Five, the thesis recommends that:

- At the global level, the CBD might formulate additional resolutions to correspond with technological advancement in marine geoengineering. It might explore and evaluate the role of marine geoengineering as a potential tool for minimizing climate change and ocean acidification.
- The periodic Ocean and Climate Change Dialogue, reports from the IPCC's Working Groups II and III, and meetings of the Conference of Parties present the UNFCCC with an avenue to enhance the understanding and governance of marine geoengineering activities globally.
- The amendments of the London Protocol do not apply to all marine geoengineering techniques. Also, the prioritization of five marine geoengineering techniques by the Contracting Parties to the Protocol poses a challenge to the governance of the non-prioritized techniques.

[22] Articles of Association for the Establishment of an Economic Community of West Africa, 4 May 1967, 595 UNTS 287 (entered into force on 4 May 1967), Art. 1 [ECOWAS Treaty].

- The Secretariat of CBD may convene workshops on marine geoengineering that involve representatives from other multiple regimes. The expertise of these regimes could be valuable to develop a robust governance framework for marine geoengineering.
- The UNEA must revisit the draft resolution on geoengineering introduced by Switzerland in 2019. UNEA has played an instrumental role in negotiating several agreements and globally serves as an avenue to decide whether there is a need for a new marine geoengineering treaty. The new treaty could be negotiated under the UNFCCC regime or as a standalone agreement.
- At the regional level, West African countries must adopt the London Protocol and its amendments to promote robust governance of marine geoengineering in the region.
- The Contracting Parties to the Abidjan Convention can adopt a Protocol under the Convention containing specific geoengineering activities rules. The Contracting Parties to the Abidjan Convention can adopt a Protocol under the Convention containing specific rules on geoengineering activities.
- The Contracting Parties to the Abidjan Convention and the climate organs of the AU must adopt binding resolutions on marine geoengineering to protect the environment against the dangers of these technologies.

1.1 Methodology

The methodological and theoretical approach(es) employed in any legal scholarship underscores the nature of the question that the scholar seeks to answer.[23] This thesis seeks to answer the research question: *How can the West African region improve its governance regime to ensure*

[23] Robert Cryer et al., *Research Methodologies in EU and International Law* (Oxford: Hart Publishing, 2011), at 8 and 9.

effective governance of marine geoengineering activities in the sub-region? Thus, this thesis conducts the research relying on three methodologies: doctrinal, legal history, and comparative legal analysis.

The doctrinal approach is an offshoot of legal positivism. It is suited for legal scholarships that seek to analyze legal norms, understand the relationships between different bodies of legal norms, or analyze the decisions of courts.[24] In this context, the thesis employs the doctrinal legal research in Chapter Three, Four, and Five to analyze global and regional environmental instruments on marine geoengineering. Furthermore, the thesis uses this methodical approach to understand the role and contributions of entities such as the UNEP, the Conference of Parties (COP), the Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), Baltic Marine Environment Protection Commission (HELCOM), OSPAR Commission, and the African Union (AU) in establishing a governance framework for marine geoengineering activities either at the global or regional level.

Historical legal analysis methodology involves the study of the history of law, or law and history, or law in history.[25] This methodological approach is crucial to this research because it ensures that the thesis pays "close attention to what is happening – or happened"[26] in the space of marine geoengineering governance. This methodological approach features in the thesis, especially in discussing the global governance framework under Chapter Three. The thesis traces the evolution of marine geoengineering activities under the CBD and the London Convention and London Protocol. By tracing the legal history, it will become apparent to the reader that the evolution of the governance of ocean fertilization - and subsequently, all marine geoengineering

[24] Ibid., 38.
[25] Sarah E. Hamill, "Review of Legal History" (2019) 28:4 Social and Legal Studies 538-559 at 539.
[26] Ibid., 551.

activities – started with the issue of a ‘statement of concern’, metamorphosed into the adoption of resolutions, and eventually produced an amendment to a treaty to ensure the effective governance of marine geoengineering.[27] Additionally, by tracing the history antecedence of marine geoengineering governance, the object, and purpose of these regimes (in the context of marine geoengineering) is unearthed to guide the regional attempts in governing these technologies.

Researchers have established a nexus between comparative law and public international law.[28] According to K. Zweigert, the understanding of what constitutes 'the general principles of law recognized by civilized nations,' stated as a source of international law by article 38 of the Statute of the International Court of Justice, relies on comparative law[29].[30] Furthermore, comparative legal analysis methodology is relevant in interpreting treaties, and understanding the concepts and institutions of customary international law.[31] Concepts such as *pacta sunt servanda* emanated from municipal laws; thus comparative law could contribute to the understanding of these concepts.[32]

The study does not look at national legal systems, but it compares regional seas program. The justification for limiting the comparative analysis to the regional level is that the nature of governing marine geoengineering is at a scale that it must be at least regional. The impact and scale of this enterprise may exceed the application of national legal systems, especially where the activity is done in the high seas.

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[27] See Chapter Three for further discussion on this subject matter.
[28] K. Zweigert & H. Kotz, *An Introduction to Comparative Law* (Oxford: Oxford University Press, 1998) at 7 and 8.
[29] Statute of the International Court of Justice, 26 June 1945 33 UNTS 993 (entered into force 24 October 1945).
[30] See, K. Zweigert & H. Kotz, *supra* note 28 at 8.
[31] Ibid.
[32] Ibid.

Furthermore, the approach in the regulation of carbon sequestration activities differs at the regional level. In regions such as the North-East Atlantic, the Contracting States have amended the regional treaty to ensure the effective governance of carbon sequestration activities in the ocean[33] In the Baltic Sea, the regional sea Convention operates alongside other regional regulations (from the European Union (EU) to govern such activities.[34] Thus, the use of comparative legal analysis offers the thesis with an avenue to propose dynamic ways of governing marine geoengineering activities in West Africa. The thesis selects these three regional seas programs because they are mature and have a good representation of developed countries. Thus, they have the capacity to deal with the legal issues engulfing marine geoengineering governance.

The thesis is affected by the limitation that comparative legal analysis often fails to consider fundamental issues of social and economic factors present in other regions. This shortfall is a limitation of the thesis, especially in discussing the regional governance regimes of marine geoengineering. The social and economic context of West Africa, the Baltic Sea, the Mediterranean Sea, and the North-East Atlantic are absent and beyond the scope of the thesis.

Finally, the discussion so far does not attribute any methodological approach to Chapter Two. This Chapter is the interdisciplinary element of the project, where the thesis explains the different examples of marine geoengineering techniques. Chapter Two serves as the springboard on which the subsequent chapters of this thesis launch their methodologies.

[33] See Chapter Four for an elaborate discussion.
[34] Ibid.

CHAPTER TWO: MARINE GEOENGINEERING TECHNIQUES AND ITS IMPACTS

This Chapter discusses geoengineering and its classifications. Over the years, different institutions and scholars have tried to define geoengineering and have produced various definitions. The literature broadly classifies geoengineering into two groups – carbon dioxide removal and solar radiation management. The following parts will elaborate on these techniques in detail.

Furthermore, it looks at several marine geoengineering techniques and their impacts on the environment, particularly the marine environment. In this regard, the following parts discuss marine geoengineering techniques such as ocean fertilization, carbon storage in the ocean, artificial upwelling, artificial downwelling, enhancing ocean alkalinity, methane capture and destruction, ocean reflectivity, marine cloud brightening, ocean thermal energy conversion (OTEC), and deep-water source cooling.

2.1 Geoengineering

The term' geoengineering' has been around since the 1970s.[35] Marchetti first coined it in the early 1970s to describe the capturing of carbon dioxide concentration in the atmosphere because of the combustion of fossil fuel and injecting it into the deep ocean.[36] The term entered mainstream climate change discussion in the early 1990s after the publication of the 1992 United States of America (USA) National Academy of Science (NAS) assessment on global warming.[37]

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[35] Cesare Marchetti, "On Geoengineering and the CO2 Problem" (1977) 1:1 Climate Change 59-68.
[36] Ibid.
[37] National Academy of Sciences *Policy, Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (2009: National Academy Press, Washington); David W. Keith, "Geoengineering the Climate: History and Prospect" (2000) 25 Annual Review of Energy and the Environment 245- 284.

However, the article published by Paul Crutzen in 2006 advocating for the injection of sulfur into the stratosphere to reflect sun radiations into space for purposes of cooling the planet is regarded as the singular activity inciting modern debate on geoengineering.[38]

Global and domestic entities have developed several definitions of geoengineering. At the international level, agencies under the United Nations (UN), mainly, have defined geoengineering. The Convention on Biological Diversity (CBD), per decision X/33, defines *geoengineering* as "…any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large scale that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere)".[39] The Intergovernmental Panel on Climate Change (IPCC) of the United Nations Framework Convention on Climate Change (UNFCCC), in its Third Assessment Report notes that geoengineering "…involves efforts to stabilize the climate system by directly managing the energy balance of the Earth, thereby overcoming the enhanced greenhouse effect."[40]

Likewise, at the domestic level, the US and the United Kingdom (UK) have described geoengineering in proceedings and reports of government. The UK of Great Britain and Northern

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[38] Paul J. Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" (2006) 77:3-4 Climate Change 211-220. The idea of injecting sulfur into the stratosphere to address global warming was not originally Crutzen's idea. However, Crutzen is the most eminent scientist to advocate for the use of geoengineering as a means of addressing geoengineering. See Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge" (2012) 34:2 Michigan Journal International 309 at 320 [Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge"]; Naomi E. Vaughan & Timothy M. Lenton, "A Review of Climate Geoengineering Proposals" (2011) 190:3-4 Climate Change 745-790 at 746.

[39] Secretariat of the Convention on Biological Diversity, *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting*, UNEP/CBD/COP/DEC/X/33, 29 October 2010. Available at: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf. [CBD Secretariat, Decision X/33]

[40] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Synthesis Report Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* [Watson, R. T. and the Core Writing Team (eds)] (Cambridge University Press, Cambridge, United Kingdom, and New York, US) 339, online: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_TAR_full_report.pdf at 332 [IPCC, 2001].

Ireland House of Commons Science and Technology Committee describes it as "…activities specifically and deliberately designed to effect a change in the global climate to minimize or reverse anthropogenic (that is human-made) climate change."[41] Also, the US House of Representatives on Science and Technology defines *geoengineering* as "…the deliberate large-scale modification of the earth's climate systems for the purposes of counteracting [and mitigating anthropogenic[42]] climate change."[43]

Furthermore, scientific academies located in the UK and US have also proffered a definition of geoengineering. The Royal Society of the UK defines *geoengineering* as "the deliberate large-scale intervention in the Earth's climate system, to moderate global warming".[44] The 1992 USA National Academy of Science (NAS) regards geoengineering techniques as "…[an option] that would involve large-scale engineering of our environment to combat or counteract the effects of changes in atmospheric chemistry."[45]

Similarly, other scholars have described geoengineering in their works. According to David Keith, it is "…the intentional large-scale manipulation of the environment, particularly manipulation that is intended to reduce undesired anthropogenic climate change".[46] Williamson et al. defines it as the "deliberate intervention in the planetary environment of a nature and scale

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[41] The United Kingdom of Great Britain and Northern Ireland House of Commons Science and Technology Committee, *The Regulation of Geoengineering – Science and Technology Committee,* online: https://publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/22105.htm#a6.

[42] The Chairperson of the Committee on Science and Technology 'Engineering the Climate Research Needs and Strategies for International Coordination' added this portion to the Report.

[43] United States of America, House of Representatives, *Committee on Science and Technology*, 108th Congress, 1st and 2nd Sess, No. 111-62, 111-75 and 111-88 (5 November 2009, 4 February 2010, and 18 March 2010) at 221, Available at: https://www.govinfo.gov/content/pkg/CHRG-111hhrg53007/pdf/CHRG-111hhrg53007.pdf.

[44] Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (Policy Document) (London: Royal Society, 2009), Available at: https://royalsociety.org/~/media/royal_society_content/policy/publications/2009/8693.pdf.

[45] National Academy of Science, *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (Washington: National Academies Press, 1992) at 433; Naomi E. Vaughan & Timothy M. Lenton, *supra* note 38 at 745.

[46] Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge", *supra* note 37, at 245.

intended to counteract anthropogenic climate change and its impacts."[47] In short, geoengineering entails the deliberate and large-scale interference with the earth's planetary system using technologies to address climate change and its environmental impacts.

2.2 Classification of Geoengineering

Based on their mode of action, experts broadly classify geoengineering techniques.[48] There are two categories of geoengineering techniques: carbon dioxide removal (CDR) and solar radiation management (SRM).[49] CDR techniques are employed to reduce the concentration of greenhouse gases in the atmosphere by enhancing carbon sinks, including the oceans and the terrestrial biosphere.[50] Researchers use SRM techniques to reduce the planet's surface temperature by enhancing the reflectivity or albedo of the Earth or by redirecting solar radiation away from it.[51]

CDR techniques remain the least controversial and politically acceptable geoengineering technique.[52] These techniques are employed to reduce the levels of carbon dioxide in the atmosphere, thereby making it possible for outgoing long-wave (thermal infrared) heat radiation to escape conveniently.[53] Chiara Armeni and Catherine Redgwell broadly classify the techniques

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[47] Phillip Williamson et al., "Ocean Fertilization for Geoengineering: A Review of Effectiveness, Environmental Impacts and Emerging Governance" (2012) 90:6 Process Safety and Environmental Protection 475-488 at 476, Available at: https://doi.org/10.1016/j.psep.2012.10.007.
[48] David W. Keith, *supra* note 37, at 259.
[49] Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge", *supra* note 38 at 321.
[50] Ibid.
[51] Ibid.
[52] Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge", *supra* note 38 at 321.
[53] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (2019), "High Level Review of a Wide Range of Proposed Marine Geoengineering Techniques" (2019) Boyd, P.W. and Vivian, C.M.G. (eds.) Rep. Stud. GESAMP No. 98, 144 p at 16. Available at: http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques. [GESAMP].

under CDR to include land-based methods and ocean-based methods.[54] The *land-based methods* are made up of afforestation, reforestation and avoidance of deforestation, biochar, land-use management, and many others.[55] The *ocean-based methods* comprise many of the techniques discussed in the following subheading. It includes ocean fertilization, ocean upwelling, ocean downwelling, and many others.[56]

SRM is also known as Albedo Modification,[57] and it employs mechanisms to reflect the sun radiation back into the atmosphere.[58] It is a technique proposed to be used in reducing the solar radiation received by the earth either by deflecting sunlight or by increasing the reflectivity of the atmosphere, clouds, or the earth's surface.[59] SRM techniques ensure that the earth absorbs less solar radiation.[60] Chiara Armeni and Catherine Redgwell classify these techniques to include *surface albedo approaches*[61] which are meant to enhance the albedo effects of the planet by making its surface appear brighter (examples (e.g.) are white roof methods and brightening human settlements; use of more reflective crop varieties and grasslands; dessert reflectors *et cetera*); *injection of stratospheric aerosols*[62] into the stratosphere to reflect the sunlight back to space; *cloud albedo enhancement*[63] employed to cool the earth by whitening clouds over parts of the ocean through injection of cloud-condensing particles into the atmosphere (e.g. increasing

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[54] Chiara Armeni and Catherine Redgwell, "International Legal and Regulatory Issues of Climate Geoengineering Governance: Rethinking the Approach" (2015) Climate Geoengineering Governance Working Paper Series: 021 at 6, Available at: https://www.jura.uni-freiburg.de/de/institute/ioeffr2/downloads/lger/armeni-redgwell-international-legal-and-regulatory-issues-of-climate-geoengineering-governance.pdf.
[55] Ibid., 6.
[56] Ibid., 6.
[57] GESAMP, *supra* note 53 at 6.
[58] Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge", *supra* note 38 at 326.
[59] Ibid.
[60] Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty (2009)* at 18, available at: https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2009/8693.pdf at IX.
[61] Chiara Armeni and Catherine Redgwell, supra note 54 at 7.
[62] Ibid.
[63] Ibid.

ocean reflectivity and marine cloud brightening techniques, as will expand below); and *space-based techniques*[64] for reducing solar radiation by positioning sun-shields into space to reflect or deflect the solar radiation.

Marine geoengineering is cross-functional. Whereas ocean fertilization, ocean upwelling, and downwelling are CDR techniques, marine cloud brightening and increasing ocean reflectivity techniques are classified as SRM techniques.

2.3 Marine Geoengineering Techniques and Their Potential Impacts.

Over the years, several marine geoengineering techniques have evolved. This part describes the processes involved in selected marine geoengineering activities, the potential contribution of these processes, and the impacts they could have on the marine environment.

2.3.1 Ocean Fertilization.

Ocean fertilization is the concept of stimulating primary productivity in the oceans to increase the population of phytoplankton in the ocean.[65] Phytoplankton are microscopic marine organisms that can store carbon through the natural process of photosynthesis.[66] The role of phytoplankton in storing carbon through ocean fertilization is that it can store carbon for about a century when they settle at the depth of the ocean.[67]

Scientists fertilize ocean using micro and major nutrients such as iron, nitrogen, or phosphorus.[68] The process involves the deliberate addition of nutrients such as iron and other

[64] Ibid.
[65] Royal Society, *supra* note 26 at 18; C. Branson, "A Green Herring: How Current Ocean Fertilization Regulation Distracts from Geoengineering Research" (2014) 54:1 Santa Clara Law Review 163 at 168.
[66] Royal Society, *Ibid*.
[67] Ibid.
[68] GESAMP, *supra* note 53 at 42-46.

trace materials to the ocean to enhance the population of phytoplankton in the ocean.[69] Besides having to add these nutrients deliberately, there are instances where these nutrients are added into the ocean through natural phenomenon such as volcanic eruptions,[70] or by wind as in the form of sand or dust storms.[71]

Ocean Iron Fertilization

In ocean fertilization experiments, researchers commonly use iron as a micronutrient. However, iron, as an isolated micronutrient, cannot dissolve in seawater[72] unless mixed with other nutrients.[73] Ordinarily, iron is insoluble in seawater; thus, to carry out ocean fertilization experiments, it is dissolved in other chemical compounds to produce iron sulfate which is then dissolved in acidified seawater before pumped into the ocean behind a moving vessel.[74] Nevertheless, proponents have proposed adding chemical complexing agents – which are patented – to keep iron in an acidic form for a longer duration.[75]

Ocean iron fertilization research focuses on areas of the ocean where there is a deficiency in phytoplankton growth. Researchers have identified areas of the ocean with High Nutrients (Nitrogen and Phosphorus) Low Chlorophyll as the locations to conduct ocean iron fertilization

[69] Sherry P. Broder and Marcus Haward, "The International Legal Regimes Governing Ocean Iron Fertilization" (2013) Regions, Institutions, and Law of the Sea: Studies in Oceans Governance 185-220 at 195.
[70] Roberta C. Hamme et al., "Volcanic Ash Fuel Anomalous Plankton Bloom in Subarctic Northeast Pacific" (2010) 31:19 Geophysical Research Letters 1-5 at 2; GESAMP, *supra* note 53 at 42-46.
[71] James K. B. Bishop et al, "Robotics Observations of Enhanced Carbon Biomass and Export at 55°S During SOFeX", Available at: https://www.science.org/doi/10.1126/science.1087717; Sherry P. Broder and Marcus Haward, *supra* note 69 at 195; GESAMP, *supra* note 53 at 43.
[72] GESAMP, *supra* note 53 at 42-46
[73] Sherry P. Broder and Marcus Haward, *supra* note 69 at 195.
[74] Phillip Williamson et al., *supra* note 47 at 477.
[75] Ibid.

experiments.[76] Scientists have discovered that by adding iron sulfate to the regions of the ocean exhibiting signs of High Nutrient Low Chlorophyll, it stimulates an increase in phytoplankton blooms.[77] Currently, researchers have identified the Southern Ocean and the Eastern Tropical Pacific as locations where there is a deficiency in naturally occurring iron.[78] The rationale for ocean iron fertilization is to add iron to the ocean, particularly in the High Nutrient Low Chlorophyll region, to facilitate the growth of phytoplankton within that area and allow them to utilize the unused nutrients.[79] Eventually, a bloom of phytoplankton will result in an increase in photosynthesis which will result in the sequestration of carbon dioxide from the atmosphere.[80]

Ocean fertilization activities have attributed many adverse effects. Mesoscale iron fertilization experiments have observed the development of toxic species of diatoms during the experiments.[81] The experiments demonstrate that iron fertilization could increase biomass of diatom species from the genus *Pseudo-nitzschia* which produces domoic acid – a neurotoxin – capable of causing significant harm to the marine ecosystem.[82] Also, potent greenhouse gases such as methane and nitrous oxide are produced during the subsurface decomposition of phytoplankton.[83]

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[76] John J. Cullen, "Hypotheses to Explain High-Nutrient Conditions in the Open Area" (1991) 36:6 *Limnology Oceanography* 1578-1599 at 1578; P. W. Boyd et al., "Mesoscale Iron Enrichment Experiments 1992-2005: Synthesis and Future Directions" (2007) 315:5812 *Science* at 612-617 at 612. [John J. Culen, Hypotheses to Explain High-Nutrient Conditions in the Open Area"].
[77] Melissa Eick, "A Navigational System for Uncharted Waters: The London Convention and London Protocol's Assessment Framework on Ocean Fertilization" (2010) 46 *Tulsa L. Rev* 351 at 351.
[78] J. H. Martin et al., "Iron Deficiency Limits Phytoplankton Growth in Antarctic Waters" (1990) 4 *Global Biogeochemistry Cycle* 5-12; P. W. Boyd et al., *supra* note 76.
[79] GESAMP, *supra* note 53 at 42.
[80] Ibid.
[81] Mary W. Silver et al., "Toxic Diatoms and Domoic Acid in Natural and Iron Enriched Waters of the Oceanic Pacific" (2010) 107:48 *Proceedings of the National Academy of Sciences* 20762 – 20767 at 20764; Charles G. Trick et al., "Iron Enrichment Stimulates Toxic Diatom Production in High-Nitrate, Low-Chlorophyll Areas" (2010) 107:13 *Proceedings of the National Academy of Sciences of the United States of America* 5887-5892 at 5888.
[82] Ibid., Mary W. Silver et al.
[83] C. S. Law, "Predicting and Monitoring the Effects of Large-Scale Ocean Iron Fertilization on Marine Trace Gas Emissions" (2011) 364 Marine Ecology Progress Series 283 – 288 at 285.

Nitrogen & Phosphorus (Macronutrients) Ocean Fertilization

Low-Nutrient Low Chlorophyll waters could be fertilized with nitrogen and phosphorus to enhance the production of fish, as well as sequester carbon.[84] The low latitudes region of the ocean comprising of the tropics and sub-tropics is identified as lacking nitrogen or phosphorus needed for primary production and the sequestration of carbon in the deepest parts of the ocean.[85]

The fertilization of Low Nutrient Low Chlorophyll areas of the sea involves deploying three distinct methods.[86] The first method is to add nitrogen to the water with excess phosphorus.[87] The next is to fertilize the Low-Nutrient Low Chlorophyll region with only nitrogen continuously.[88] The third method is to add both nitrogen and phosphorus to the region continuously.[89]

Furthermore, ocean nitrogen and phosphorus fertilization pose significant harm to the environment. Like ocean iron fertilization, it produces harmful algal blooms in coastal zones.[90] There is also the danger of nutrients enrichment through agricultural runoff resulting in dead zones.[91]

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[84] GESAMP, *supra* note 53 at 48-49.
[85] Curtis Deutsch et al., "Spatial Coupling of Nitrogen Inputs and Losses in the Ocean" (2007) 445:11 *Nature* 163 - 167 at 163; C. M. Moore et al., "Processes and Patterns of Oceanic Nutrient Limitation" (2013) 6 *Nature Geoscience* 701 – 710 at 704.
[86] Daniel P. Harrison, "Global Negative Emissions Capacity of Ocean Macronutrient Fertilization" (2017) 12:3 Environmental Research Letters 1-10 at 2.
[87] Ibid.
[88] Ibid.
[89] Ibid.
[90] Patricia M. Gilbert et al., "The Haber Bosch-Harmful Algal Bloom (HB-HAB) Link" (2014) 9:10 Environmental Research Letters 1 -13 at 4.
[91] Robert J. Diaz and Rutger Rosenberg, "Spreading Dead Zones and Consequences for Marine Ecosystems" (2008) 321: 5891 *Science* 926-929 at 926.

2.3.2 Carbon Storage in the Ocean.

The ocean can store significant amounts of carbon dioxide.[92] The deep ocean stores about 70 tera tonnes of carbon dioxide in the global carbon system.[93] It can store over 85% of the excess carbon dioxide produced due to the burning of fossil fuels[94] for several centuries.[95] The velocity at which the ocean circulates determines the rate of carbon uptake by the ocean surface. It is estimated to be between 200 to 1000 years.[96]

Different ocean areas are suitable locations to store carbon. Liquid or solid carbon dioxide could be stored in the mid/deep ocean depth, on the seabed, placed into unconsolidated deep-sea sediments, or in geological structures beneath the seabed or the deep ocean.[97] The next sub-parts will explain the techniques used to store the liquid and solid carbon in these parts of the ocean.

Carbon Storage in the Mid/Deep Ocean

Storage of carbon in the deep ocean is an idea that has existed since the 1970s.[98] The artificial means of injecting liquid carbon dioxide in the mid/deep ocean depths is an artificial means of adding carbon dioxide directly to the deep ocean without having to rely on the natural cycle of

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[92] Hans Aksel Haugen and Lars Ingolf Elde, "CO2 Capture and Disposal: The Realism of Large Scale Scenarios" (1996) 37:6-8 Energy Conversion and Management 1061 -1066, available at: https://doi.org/10.1016/0196-8904(95)00298-7 at 1062; GESAMP, *supra* note 53 at 52.

[93] Jorge L. Sarmiento and Gruber, "Sinks for Anthropogenic Carbon" (2002) 55:8 Physics Today 30-36, available at: https://doi.org/10.1063/1.1510279; GESAMP, *supra* note 53 at 49.

[94] James C. Orr et al., "Estimates of Anthropogenic Carbon Uptake from Four Three-Dimensional Global Ocean Models" (2001) 15:1 AT 43-60 at 43; GESAMP, *supra* note 53 at 49.

[95] Intergovernmental Panel on Climate Change (IPCC), 2005*: Special Report on Carbon Dioxide Capture and Storage Prepared by Working Groups III to the Intergovernmental Panel on Climate Change,* [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)] (Cambridge University Press, Cambridge, United Kingdom, and New York, US) 442, online: https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_wholereport-1.pdf at 280.

[96] Ibid., IPCC, 2005 at 197.

[97] GESAMP, *supra* note 53 at 49 to 60.

[98] Cesare Marchetti, *supra* note 35.

200 to 1000 years.[99] It was first suggested by Marchetti[100] and was subsequently discussed by the IPCC in its report on carbon dioxide and storage in 2005.[101] According to literature, recent attempts to conduct a study in Hawaii and Norway have received public backlash and negative public publicity.[102]

The storage of carbon dioxide in the mid and deep oceans involves injecting cooler liquid carbon dioxide into the deep ocean at high pressure. The process involves injecting liquid carbon dioxide cooler than 5 degrees Celsius (°C) at a depth greater than 2,800 meters (m) and a pressure of 28 MegaPascal (MPa) into the ocean.[103] At these pressures and temperatures, the liquid carbon dioxide weighs more than seawater. Thus, makes the injected carbon dioxide sink to the bottom and dissolves during sinking if appropriately dispersed.[104] When it dissolves in the seawater, it forms carbonic acid, which further dissociates into bicarbonate and carbonate.[105] After dissociating, the hydrogen from the carbonic acid is released as hydrogen ions.[106] The entire process increases the dissolved inorganic carbon pool stored for centuries in the deep ocean depth.[107] Centuries later, the natural cycle of the ocean elevates the water parcel

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[99] GESAMP, *supra* note 53 at 47.
[100] Cesare Marchetti, *supra* note 35 at 61.
[101] IPCC, 2005 *supra* note 95 at 48.
[102] Eric Adam et al, "International Field Experiment on Ocean Carbon Sequestration" (2002) 36:21 Environmental Science & Technology 399, available at: https://doi-org.ezproxy.library.dal.ca/10.1021/es022442b ; Virginia Gewin, "Ocean Carbon Study to Quit Hawaii" (2002) 417:6892 Nature (London) 888-888, available at: https://doi.org/10.1038/417888b; Jim Giles, "Norway Sinks Ocean Carbon Study" (2002) 419:6902 Nature (London) 6-6, available at: https://doi.org/10.1038/419006b; Clair Gough et al., "Burying Carbon Under the Sea: An Initial Exploration of Public Opinions" (2002) 13:6 Energy & Environment 883-900 at 888, available at: https://www.jstor.org/stable/43734534?sid=primo.
[103] GESAMP, *supra* note 53 at 47.
[104] Ibid.
[105] Thereby decreasing the acidity of the seawater because the by products are alkaline compounds.
[106] Ibid.
[107] Ibid.

(containing the dissolved inorganic carbon) to the surface of the water which leads to the re-entry of carbon dioxide into the atmosphere.[108]

The activity could adversely impact the marine environment. There is a lack of understanding about the way liquified carbon dioxide behaves when injected and dissolved in a natural seawater environment.[109] The deep sea possesses commercial, environmental, and cultural value, which calls for future research into the value of the deep sea.[110] This raise concerns in the implementation of storage of carbon within the mid and deep-sea oceans. The addition and dissolution of liquified carbon dioxide in the deep water increases the ocean's acidity compared to surface water. It is because deep water is less buffered and below conditions at which calcium carbonate particles dissolve,[111] therefore making the water corrosive and affecting the fragile deep ocean ecosystem.[112]

Storage of Liquid Carbon Dioxide on the Seabed

Placing liquified carbon dioxide on the seabed could store it in the ocean.[113] At a depth greater than 2,800m and a pressure of 28 MPa, liquid carbon dioxide at about 5 degrees can be stored in the ocean.[114] The temperature and pressure of the carbon dioxide makes it denser than the surrounding seawater, thus causing it to sink to the bottom.[115]

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[108] Fabian Reith et al., "Revisiting Ocean Carbon Sequestration by Direct Injection: A Global Carbon Budget Perspective" (2016) 7:4 Earth System Dynamics 797-812 at 799.
[109] IPCC, 2005 supra note 95; Steve Goldthorpe, "Potential for Very Deep Ocean Storage of CO2 Without Ocean Acidification: A Discussion Paper" (2017) 114 Energy Procedia 5417-5429 at 5419.
[110] Maja Vinde Folkerson et al., "The Economic Value of the Deep Sea: A Systematic Review and Meta-Analysis" (2018) 94 Marine Policy 71-80; A. R. Thurber et al., "Ecosystem Function and Services Provided by the Deep Sea" (2014) 11:14 Biogeosciences 3941-3963 at 3949-3450.
[111] GESAMP, *supra* note 53 at 50.
[112] Ibid.
[113] Ibid., 51.
[114] Ibid.
[115] Ibid.

The storage of carbon dioxide on the seabed involves several methods. Capron et al. propose the use of geosynthetic containers to store carbon dioxide on the seabed.[116] In this context, the storage could be done in two ways, either by storing: (a) solid carbon dioxide hydrate in geosynthetic containers at depths over 500m; or (b) liquid carbon dioxide in geosynthetic containers at depths below 3,000m.[117] Additionally, other scholars propose that carbon dioxide can be stored in a glass capsule and deposited on the deep seabed.[118]

There is limited knowledge of how liquefied carbon dioxide behaves in the ocean, and only a handful of small-scale studies have verified the stability of liquid carbon dioxide on the ocean floor of the deep sea.[119] The study established that covering the seafloor with liquid carbon dioxide made it uninhabitable for marine organisms. However, there was no evidence of the activity having an impact on fauna despite the increase in the volume of carbon dioxide and the increase in the acidity of the locality where the study was conducted.[120]

Liquid carbon dioxide stored on the seabed poses significant harm to the ocean. The sudden increase in carbon dioxide levels can significantly impact disposal areas since these areas are often unexplored. Likewise, the liquid carbon dioxide stored on the seabed would destroy established life found in the sediments.[121] Furthermore, where geosynthetic containers store

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[116] Mark E. Capron et al., "Secure Seafloor Container CO2 Storage" (2013) Oceans 1-8.
[117] Ibid.
[118] Stefano Caserini et al., "Evaluation of a New Technology for Carbon Dioxide Submarine Storage in Glass Capsules" (2017) 60 International Journal of Greenhouse Gas Control 140-155.
[119] Peter G. Brewer et al., "Deep-Sea Field Test of the CH4 Hydrate to CO2 Hydrate Spontaneous Conversion Hypothesis" (2014) 28:11 Energy & Fuels 7061-7069; IPCC, 2005 *supra* note 95 at Chp 6; GESAMP, *supra* note 53 at 51.
[120] Ibid.
[121] Eric E. Adams and Ken Caldeira, "Ocean Storage of CO2" (2008) 4:5 Elements 319-324 at 322; James P. Barry et al., "Effects of Direct Ocean CO2 Injection on Deep-Sea Meiofauna" (2004) 60:4 Journal of Oceanography 759-766; Fumio Inagaki et al., "Microbial Community in a Sediment-Hosted CO2 Lake of the Southern Okinawa Through Hydrothermal System" (2006) 103:38 Proceedings of the National Academy of Sciences 14164-14169 at 14169; IPCC, 2005 supra note 61; Jun Kita and Takashi Ohsumi, "Perspectives on Biological Research for CO2 Ocean Sequestration"(2004) 60:4 Journal of Oceanography 695-703 at 695; B. A. Seibel and P. J. Walsh, "Carbon Cycle: Potential Impacts of CO2 Injection on Deep-sea Biota" (2001) 294:5541 Science 319-320.

carbon on the sea floor, any leakage from the container could have similar impacts as those stored on deep ocean depths.[122]

Storage of Carbon into Unconsolidated Deep-Sea Sediments

Seabed sediment is an avenue to store carbon dioxide. This idea was first proposed in 1997 and it involves the injections of liquid carbon dioxide into the deep-sea sediments at depths of more than 3,000m.[123] According to House et al., the total storage capacity in deep-sea sediments is massive compared to the current carbon dioxide emission.[124] At this depth, the stored carbon dioxide is guaranteed to be stable for a prolonged duration due to the high pressures and low temperatures.[125] Also, at this depth, the liquid carbon dioxide is denser than the pore fluid, thereby making it gravitationally stable.[126] Eventually, the carbon dioxide dissolves in the pore fluid and forms a solution that is slightly denser than the surrounding pore fluid.[127] Nevertheless, House et al. and Qanbari et al. argue that the density of carbon dioxide declines faster than that of seawater as the depth below the ocean floor increases, and there is an increase in temperature in the sediment.[128] To facilitate the rate at which the storage is done, Murray et al propose to

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[122] GESAMP, *supra* note 53 at 53.
[123] Koide et al., "Deep Sub-Seabed Disposal of CO2: The Most Protective Storage" (1997) 38:1 Energy Conversion and Management s253-s258 at s254. [Koide et al., "Deep Sub-Seabed Disposal of CO2"]; Koide et al., "Hydrate Formation in Sediments in the Sub-Seabed Disposal of CO2" (1997) 22:2-3 Energy 279-283. [Koide et al., "Hydrate Formation in Sediments in the Sub-Seabed Disposal of CO2"].
[124] Kurt Zenz House et al., "Permanent Carbon Dioxide Storage in Deep-Sea Sediments" (2006) 103:33 Proceedings of the National Academy of Sciences 12291-12295 at 12295; Daniel P. Schrag, "Preparing to Capture Carbon" (2009) 315:5813 Science 812-813. GESAMP, *supra* note 53 at 55.
[125] Koide et al., "Hydrate Formation in Sediments in the Sub-Seabed Disposal of CO2", *supra* note 89; Ibid., Kurt Zenz House et al.; Farhad Qanbari et al., "Storage of CO2 as Hydrate Beneath the Ocean Floor" (2011) 4 Energy Procedia 3997-4004 at 3999.
[126] J. S. Levine et al., "Gravitational Trapping of Carbon Dioxide in Deep Sea Sediments: Permeability, Buoyancy, and Geomechanical Analysis" (2007) 34:24 Geophysical Research Letters L24703-n/a at L24703.
[127] Kurt Zenz House et al., supra note 124.
[128] Ibid., Kurt Zenz House et al.; Farhad Qanbari et al., *supra* note 125 at 4003.

design torpedo shapes in solid carbon dioxide that could penetrate some distance into the deep-sea sediments.[129]

The storage of carbon dioxide in seabed sediments potentially impacts the marine environment. In the case of liquid carbon dioxide storage, any micro-iota and bacteria within the injected liquid carbon dioxide are likely to be harmed.[130] However, at its initial depth, there is a belief that there will be minimal effects liquid carbon dioxide on the chemistry and biology of the seabed and overlying seawater.[131] Moreover, where the proposed solid carbon dioxide torpedo is employed, it is expected that there will be significant impacts on the chemistry and biology of the seabed and superjacent waters.[132] But in general, the sequestration of carbon dioxide storage under deep-sea sediments is considered to be safe and permanent.[133]

Storage of Carbon in Geological Structures Beneath the Seabed

Geological structures under the seabed could store carbon dioxide.[134] Seifritz is credited to be the first person to mention the use of mineral silicates to form carbonates in an engineering context.[135] However, Lackner et al. studied the concept in-depth.[136] The concept involves the injection of gaseous carbon dioxide into basalt and peridotite rocks where it reacts with the calcium and magnesium rock to form stable carbonate minerals.[137] In the ocean, basalt rocks are

[129] C. N. Murray et al., "Permanent Storage of Carbon Dioxide in the Marine Environment: The Solid CO2 Penetrator" (1996) 37:6-8 Energy Conversion and Management 1067-1072 at 1068.
[130] GESAMP, *supra* note 53 at 55.
[131] Ibid.
[132] Ibid.
[133] Yihua Teng and Dongxiao Zhang, "Long-Term Viability of Carbon Sequestration in Deep-Sea Sediments" (2018) 4:7 Sciences Advances eaao6588-eaao6588 at eaa06588.
[134] GESAMP, *supra* note 53 at 56.
[135] W. Seifritz, "CO2 Disposal by Means of Silicate" (1990) 345:6275 Nature 486-486.
[136] Klaus S. Lackner et al., "Carbon Dioxide Disposal in Carbonate Minerals" (1995) 20:11 Energy 1153-1170.
[137] Jurg M. Matter and Peter B. Kelemen, "Permanent Storage of Carbon Dioxide in Geological Reservoirs by Mineral Carbonation" (2009) 2:17 Nature Geoscience 837-841 at 837; Peter B. McGrail et al., "Potential for Carbon Dioxide Sequestration in Flood Basalts" (2006) 111: B12 Journal of Geophysical Research B12201-n/a.

found under the seabed, thereby making their location conducive for storing carbon.[138] Unlike the storage of carbon in unconsolidated deep-sea sediments, this technique can be carried out in shallower depths of the ocean because carbon dioxide is not stored as liquid, thereby making it react with the minerals in the rocks to form new minerals.[139]

The CarbFix project is the only large-scale study of this technique.[140] The only large-scale studies of the storage of carbon in geological structures beneath the seabed were carried out by CarbFix – a project first funded by the European Commission[141] and the European Union.[142] The researchers carried out this project on the land,[143] and they discovered that the CarbFix site mineralized over 95% of the injected carbon dioxide into carbonate minerals in less than two years.[144]

The potential impacts of storing carbon beneath the ocean seabed on the marine environment must be better understood. However, researchers have stated that injected carbon dioxide does affect the microbes living in basalts in the ocean.[145]

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[138] David S. Goldberg et al., "Carbon Dioxide Sequestration in Deep-Sea Basalt" (2008) 105:29 Proceedings of the National Academy of Sciences 9920-9925 at 992; David S. Goldberg et al., "Potential On-shore and Off-shore Reservoirs for CO2 Sequestration in Central Atlantic Magmatic Province Basalts" (2010) 107:4 Proceedings of the National Academy of Sciences 1327-1332; David S. Goldberg & Angela L. Slagle, "A Global Assessment of Deep-sea Basalt Sites for Carbon Sequestration" (2009) 1:1 Energy Procedia 3675-3682.

[139] GESAMP, *supra* note 53 at 55.

[140] Ibid., 56.

[141] Edda S. P. Aradottir et al. "CarbFix Final Report". Available at: https://cordis.europa.eu/docs/results/283/283148/final1-carbfix-final-report-vff.pdf.

[142] https://www.eeas.europa.eu/delegations/iceland/carbfix-innovative-icelandic-climate-solution-supported-european-union_en?s=212#:~:text=The%20EU%20is%20committed%20to,from%20the%20EU%27s%20Innovation%20Fund.

[143] Rosalia Trias et al., "High Reactivity of Deep Biota Under Anthropogenic CO2 Injection into Basalt" (2017) 8:1 Nature Communications 1 -14 at 2.

[144] Juerg M. Matter et al., "Rapid Carbon Mineralization for Permanent Disposal of Anthropogenic Carbon Dioxide Emissions" (2016) 352:6291 Science 1312-1314.

[145] Trias et al., *supra* note 143.

Storage of Carbon in the Deep Ocean by Depositing Crop Wastes

Carbon dioxide could be stored over hundred to thousand centuries in the ocean by depositing crop waste in the deep ocean.[146] At the turn of the century, Mertzger and Benford proposed that depositing crop residues such as corn, wheat, and soybeans into the ocean could allow the oceans or major rivers to store 12% of carbon emissions from the United States of America (USA).[147] In 2009, Strand and Benford further developed this idea and proposed using stones to propel crop residue into the ocean.[148] Capron et al. suggested using geosynthetic containers to contain the residue deposited into the ocean, particularly concerning the containment of crop residues in the deep ocean.[149]

There is a challenge to the feasibility of the deposit of crop waste into the ocean. The use of crop waste to generate electricity in a power plant fitted with carbon capture and storage devices would rather be more efficient than depositing it in the deep ocean.[150] In addition, crop residues perform biological, chemical, and physical roles that are crucial for sustaining soil resources.[151] Karlen et al. opine that crop residue performs:

> multiple biological, chemical, and physical roles that are crucial for sustaining the soil resources upon which humans depend for food, feed, fiber, and, most recently, feedstocks for biofuel. Crop residues protect soil resources from wind

[146] GESAMP, *supra* note 53 at 57.
[147] Robert A. Mertzger & Gregory Benford, "Sequestering of Atmospheric Carbon Through Permanent Disposal of Crop Residue" (2001) 49:1-2 Climate Change 11-19 at 17.
[148] Mark E. Capron et al., *supra* note 116; Stuart E. Strand & Gregory Benford, "Ocean Sequestration of Crop Residue Carbon: Recycling Fossil Fuel Carbon Back to Deep Sediments" (2009) 43:4 Environmental Science & Technology 1000-1007 at 1002.
[149] Mark E. Capron et al., *supra* note 116.
[150] Douglas L. Karlen et al., "Crop Residues: The Rest of the Story"(2000) 43:21 Environmental Science & Technology 8011-8015; David W. Keith and James S. Rhodes, "Bury, Burn or Both: A Two-For-One Deal on Biomass Carbon and Energy" (2002) 54:3 Climate Change 375-377; Robert A. Metzger et al, "To Bury or to Burn: Optimum Use of Crop Residues to Reduce Atmospheric CO2" (2002) 54:3 Climate Change 369-374 at 369.
[151] Ibid., Karlen et al.

> and water erosion, serve as food sources for micro- and macro-organisms, and enhance nutrient cycling, water relationships (infiltration, retention, and release), and soil structure".[152]

Furthermore, this technique could have adverse effects on the environment. Where the crop residues are propelled (by stones) into the sea in bulk, it could physically impact the seabed due to the sheer mass of the material covering the seabed.[153] Crop residue deposited in the deep ocean could reduce the oxygen in the ocean thereby resulting in the production of other greenhouse gases such as methane and nitrous oxide and other harmful chemicals such as hydrogen sulphide and nutrients (nitrogen and phosphorus compounds) arising out of the decomposition of the crop residue.[154] Also, the decomposition of the crop residue is likely to be at a slower rate due to the limited availability of oxygen and the low temperature in the deep ocean, the lack of marine mechanisms to breakdown the lignocellulose cells of the crop residues, and the lack of oxygen within the crop residue bales.[155] Likewise, where the crop residue bale is packaged (in a geosynthetic container), any significant leakage could contribute to the reduction in oxygen and lead to greater density and biomass of benthic organisms over a prolonged duration.[156]

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[152] Ibid.
[153] GESAMP, *supra* note 53 at 58.
[154] GESAMP, *supra* note 53 at 58.
[155] Stuart E. Strand & Gregory Benford, *supra* note 148; Richard G. Keil et al., "Burial of Agricultural Byproducts in the Deep Sea as a Form of Carbon Sequestration: A Preliminary Experiment" (2010) 122:1 Marine Chemistry 91-95 at 93-94.
[156] GESAMP, *supra* note 53 at 58.

Storage of Carbon in the Ocean by the Cultivation of Macroalgal

Another avenue to sequester carbon is the cultivation of macroalgae or kelp. The purpose of cultivating macroalgae could be for the supply of food,[157] especially in the Asian- Pacific region[158] where macroalgal cultivation accounts for 0.8 metric tons of carbon (`Mt C) annual organic carbon accumulated.[159] It is stated that the annual estimate of natural sequestration of carbon in the deep ocean and sediments by macroalgae is about 170Mt C.[160] This technique uses the cultivation of microalgal or kelp to remove carbon dioxide from the oceans through photosynthesis.[161] In addition, storing macroalgal material as part of the storage process could utilize geosynthetic containers, but the high cost of this method is estimated to make it impracticable and unattractive.[162]

The cultivation of macroalgae or kelp could generate biofuels. Chung et al. reported that macroalgae or kelp cultivation could generate biofuels, but the retention of carbon sequestered by the macroalgal is impracticable for a long timescale due to the lack of a sediment-sub-stratum link for kelp.[163] In this regard, Sondak et al. call for the conversion of the biomass into biofuels as a better option to store carbon for a more extended period.[164]

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[157] R. Pereira and C. Yarish, "Mass Production of Marine Macroalgae" (2008) 3 Encyclopedia of Ecology 2236-2247.

[158] IK Kyo Chung et al., "Using Marine Macroalgae for Carbon Sequestration: A Critical Appraisal" (2011) 23:5 Journal of Applied Phycology 877-886. [IK Kyo Chung et al., "Using Marine Macroalgae for Carbon Sequestration: A Critical Appraisal"].

[159] Calvyn F. A. Sondak et al., "Erratum to: Carbon Dioxide Mitigation Potential of Seaweed Aquaculture Beds" (2017) 29:5 Journal of Applied Phycology 2375-2376.

[160] Dorte Krause-Jensen and Carlos M. Duarte "Substantial Role of Macroalgae in Marine Carbon Sequestration" (2016) 9:10 Nature Geoscience 737-742 at 739.

[161] Carlos M. Duarte et al., "Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation" (2017) 4 Frontiers in Marine Science 1-8 at 2 and 4.

[162] GESAMP, *supra* note 53 at 59.

[163] IK Kyo Chung et al., "Installing Kelp Forests/Seaweeds Beds for mitigation and Adaptation Against Global Warming: Korean Project Overview" (2013) 70:5 ICES Journal of Marine Science 1038-1044 at 1039; [IK Kyo Chung et al., "Installing Kelp Forests/Seaweeds Beds for mitigation and Adaptation Against Global Warming: Korean Project Overview"].

[164] Calvyn F. A. Sondak et al, *supra* note 159; Carlos M. Duarte et al., *supra* note 161.

With regards to the impact of the sequestration of microalgal cultivation, there is little information available to predict the impacts of this technique on the marine environment.[165] However, there is appreciable information on the impact of microalgal cultivation on the marine environment. The wider environmental costs of seaweed aquaculture are that for non-indigenous macroalgae species, it may alter both ecosystem structure and function by changing food webs, monopolizing space, developing into ecosystem engineers, and spreading afar due to their efficient dispersal capacities.[166] The interbreeding between cultured and wild seaweeds can introduce disease-causing pathogens and parasites.[167]

There is a direct benefit of this technique beyond the sequestration of carbon. Macroalgal cultivation, particularly seaweed cultivation, provides nursery grounds for juvenile commercial fish and crustaceans, removes dissolved nutrients that may otherwise cause eutrophication,[168] and protects the underlying seabed in instances where seabed scouring through bottom-trawling would have occurred.[169]

2.3.3 Artificial Upwelling

Artificial upwelling uses marine resources to sequestrate atmospheric carbon dioxide into the ocean.[170] In the mid and low-latitude oceans, nutrients are scarce in the surface waters; as a

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[165] IK Kyo Chung et al., “Installing Kelp Forests/Seaweeds Beds for mitigation and Adaptation Against Global Warming: Korean Project Overview”, *supra* note 163; GESAMP, *supra* note 53 at 59.
[166] Ibid., 9. The Asian red seaweed *kappaphycus alvarezii* introduced to Hawaii in the 1970s has since spread to six kilometers from its initial point.
[167] Ibid.
[168] Eutrophication involves enriching the ocean with dissolved nutrients like nitrate or phosphate to enhance aquatic plant life's growth, depleting the ocean's dissolved oxygen. See GESAMP, *supra* note 53 at 135.
[169] Elizabeth J. Cottier-Cook et al., “Safeguarding the Future of the Global Seaweed Aquaculture Industry” (2016) United Nations University (INWEH) and Scottish Association for Marine Science Policy Brief 1-12, online: https://inweh.unu.edu/safeguarding-the-future-of-the-global-seaweed-aquaculture-industry/ at 8.
[170] GESAMP, *supra* note 53 at 61.

result, there are impacts on the growth of phytoplankton.[171] However, deeper waters are rich with nutrients and more dissolved inorganic carbon due to the remineralization of organic matter exported from the surface water to the ocean interior.[172] To ensure that sufficient nutrients are present in the surface waters to enhance the growth of phytoplankton, deeper nutrient-rich waters of the ocean are purposefully brought to the surface using large-scale vertical pipes in the ocean.[173]

Artificial upwelling stimulates and enhances the planet's ocean carbon storage capacity. According to Lovelock and Rapley, this process stimulates the earth's capacity to heal itself.[174] Nutrients within the ocean environment stimulate the growth of phytoplankton, unlike ocean fertilization, which involves adding nutrients (iron, nitrogen, or phosphorus) into the ocean.[175] However, there is skepticism as to whether artificial upwelling could ensure a significant reduction of carbon dioxide since upwelling nutrients contain the stoichiometric equivalent of respired carbon.[176] Artificial upwelling can cause some net marine carbon dioxide uptake in regions where upwell waters contain low carbon dioxide content.[177]

Also, artificial upwelling has added benefits beyond the sequestration of carbon. According to Kirke, upwelling can enhance fish production, cool coral reefs, and prevent or

[171] John Cullen, "Status of the Iron Hypothesis After the Open-Ocean Enrichment Experiment" (1995) 40:7 Limnology and Oceanography 1336-1343. [John Cullen, "Status of the Iron Hypothesis After the Open-Ocean Enrichment Experiment"]; D. Karl et al., "The Role of nitrogen Fixation in Biogeochemical Cycling in the Subtropical North Pacific Ocean" (1997) 388:6642 Nature 533-538 at 533, C. M. Moore et al., *supra* note 85.
[172] GESAMP, *supra* note 53 at 61.
[173] The Royal Society 2009; Jeffrey McGee et al., "Geoengineering the Oceans: An Emerging Frontier in International Climate Change Governance" (2018) 10:1 *Australian Journal of Maritime & Ocean Affairs* 67 -80.
[174] James E. Lovelock and Chris Rapley, "Ocean Pipes Could Help the Earth to Cure Itself" (2007) 449:7161 Nature 403-403.
[175] James E. Lovelock and Chris Rapley, *ibid*; GESAMP, *supra* note 53 at 60.
[176] A. Oschlies et al., "Climate Engineering by Artificial Ocean Upwelling Channeling the Sorcerer's Apprentice: Ocean Pipe Impacts" (2010) 37:4 Geophysical Research Letters 1-5; Andrew Yool et al., "Low Efficiency of Nutrient Translocation for Enhancing Oceanic Uptake of Carbon Dioxide" (2009) 114:C8 Journal of Geophysical Research C08009-n/a at C08009.
[177] GESAMP, *supra* note 53 at 61; A. Oschlies et al., ibid.

mitigate the impacts of typhoons.[178] Additionally, upwelled waters are cooler than surface waters, thereby assisting in the cooling of the ocean surface and the overlying air. Its utility as a coolant helps in mitigating global warming on local and regional scales.[179]

Like other marine geoengineering techniques, artificial upwelling has many adverse environmental effects. The ocean's thermocline is disturbed, and on centennial timescales, it may result in a high global mean temperature.[180] This is because the lower sea surface temperature reduces outgoing long-wave radiation of the sun, thereby making the earth retain more energy during the artificial upwelling process. The excess energy stored as heat in the subsurface waters is displaced downward by the overlying upwelled waters.[181] The technique can also result in a termination effect when the artificial upwelling process stops. Eventually, the additional heat stored in the subsurface and deeper ocean makes it back to the surface and results in an exponential increase in surface temperature.[182] Also, Williamson et al. note that any enhanced biological production at a scale required to mitigate climate change is likely to deplete mid-water oxygen levels and increase methane and nitrous oxide release.[183]

2.3.4 Artificial Downwelling

Artificial downwelling sequesters carbon by replacing cold 'down-welled' waters with warmer surface waters. Zhou and Flynn first proposed it as a technique that could enhance the

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[178] Brian Kirke, "Enhancing Fish Stocks with Wave-powered Artificial Upwelling" (2003) 46:9 Ocean & Coastal Management 901-915 at 902-903.
[179] GESAMP, *supra* note 53 at 60.
[180] Lester Kwiatkowski et al., "Atmospheric Consequences of Disruption of the Ocean Thermocline" (2015) 10:3 Environmental Research Letters 34016 at 1.
[181] Ibid; GESAMP, *supra* note 53 at 61.
[182] David P. Keller et al., "Potential Climate Engineering Effectiveness and Side Effects During a High Carbon Dioxide-Emission Scenario" (2014) 5:1 Nature 1-11 at 6; A. Oschlies et al., *supra* note 176.
[183] P. Williamson et al., *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters* (2016) Technical Series No. 66, 152, Secretariat of the Convention on Biological Diversity, available at: https://www.cbd.int/doc/publications/cbd-ts-66-en.pdf at 60.

sequestration of carbon by replacing cold down-welled waters with warmer surface water saturated in carbon dioxide using erected pipes within the ocean interior.[184] Eventually, when the warmer surface water cools down, it takes up more carbon dioxide via a process known as cooling-enhanced solubility.[185] Beyond the ability of the technique to sequester carbon, it is seen as an engineering solution to coastal hypoxia.[186]

There are four categories of artificial downwelling technologies; density current generator (DCG), wind-powered pump, wave-powered pumps such as WEBAP and OXYFLUX, and current-induced artificial downwelling.[187] So far, there are about 6o artificial downwelling techniques patents throughout the USA, Japan, Europe, and China.[188]

These artificial downwelling technologies, particularly DCG, may impact the marine environment. Artificial downwelling techniques could potentially cause adverse effects such as disrupting the stratification of water, modifying the water cycle, and interfering with the natural biochemical process.[189]

2.3.5 Enhancing Ocean Alkalinity

The study of the natural weathering process in rocks served as a bedrock to develop this technique.[190] The idea of replicating the natural weathering process in rocks in enhancing ocean

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[184] S. Zhou and P. C. Flynn, "Geoengineering Downwelling Ocean Currents: A Cost Assessment" (2005) 71:1-2 Climate change 203-220.
[185] GESAMP *supra* note 53 at 63.
[186] Shuo Liu et al., "Review of Artificial Downwelling for Mitigating Hypoxia in Coastal Waters" (2020) 12:10 Water (Basel) 1 – 18 at 2.
[187] Ibid., 2.
[188] Ibid., 2.
[189] Ibid., 12.
[190] GESAMP *supra* note 53 at 65; Robert A. Berner, *The Phanerozoic Carbon Cycle* (New Yor, Oxford University Press, 2004).

alkalinity was first proposed by Seifritz[191] and later studied in detail by Lackner et al.[192] According to Taylor et al. 'weathering' is the natural process by which silicate and carbonate rocks break down.[193] Hartmann et al. indicate that the reaction between carbon dioxide and silicate and carbonate rocks has regulated the earth's carbon cycle and climate for many years.[194] Within the interior of the ocean, dissolved carbon dioxide reacts with minerals which form sediments that settle on the ocean floor.[195] However, the natural process of storing carbon in geological structures beneath the seabed is a slow process which will require the contribution of human activities such as adding powdered minerals to the ocean to accelerate the process of carbon sequestration.[196]

There are several ways to increase the alkalinity of the ocean. The ocean's alkalinity could be enhanced by adding lime directly to the ocean, by adding carbonate minerals to the ocean, accelerating weathering of limestone, by open ocean dissolution of olivine, by electrochemical enhancement of carbonate and silicate mineral weathering, by spreading olivine within coastal and shelf environments, by amending cropland soils with crushed reactive silicates, or by a scientific process called brine thermal decomposition (BTD) of desalination reject brine.[197]

The enhancement of the ocean's alkalinity presents numerous benefits to the environment. By adding boosting the alkalinity of seawater, it could help to (i) increase the

[191] W. Seifritz, *supra* note 135.
[192]Klaus S. Lackner et al., *supra* note 136.
[193] Lyla L. Taylor et al., "Enhanced Weathering Strategies for Stabilizing Climate and Averting Ocean Acidification" (2016) 6:4 Nature Climate Change 402-406.
[194] Jens Hartmann et al., "Enhanced Chemical Weathering as a Geoengineering Strategy to Reduce Atmospheric Carbon Dioxide, Supply Nutrients, and Mitigate Ocean Acidification" (2013) 51:2 Reviews of Geophysics 113-149; Jeffrey McGee et al., *supra* note 173 at 72.
[195] National Research Council, *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration (*2015, The National Academies Press), online: https://nap.nationalacademies.org/read/18805/chapter/1#ii.
[196] Jens Hartmann et al., *supra* note 194.
[197] GESAMP, *supra* note 53 at 65 and 66.

ocean's carbon dioxide uptake by decreasing surface water partial pressure of carbon dioxide; (ii) counter seaweed acidity caused by excess carbon dioxide; (iii) provide a large and stable storage medium for anthropogenic carbon dioxide in the form of mineral bicarbonate and carbonate ions in seawaters;[198] (iv) and raise the carbonate saturation state of the oceans, in the processing reversing the effects of ocean acidification particularly in calcifying organisms such as corals and shellfish that are integral to marine biodiversity.[199]

Besides the advantages of increasing the ocean's alkalinity, there is insufficient knowledge about this technique to warrant an informed decision on the large-scale deployment of this technique.[200] Some of the areas identified as areas requiring further research include: (i) the characterization of the minerals or other alkalinity to be used, including specific ions and materials that would accompany alkalinity addition to the ocean;[201] (ii) the marine biological response to the addition of minerals or alkalinity to be used;[202] (iii) determination of the impact of biotic and abiotic carbonate precipitation under alkalinity addition;[203] (iv) public acceptability;[204] (v) economics and cost-effectiveness;[205] and (vi) monitoring and verification.[206]

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[198] GESAMP, *ibid* at 64.
[199] Rebecca Albright et al., "Reversal of Ocean Acidification Enhances Net Coral Reef Calcification" (2016) 531:7594 Nature 362-365; Francesca Marubini and Brenda Thake, "Bicarbonate Addition Promotes Coral Growth" (1999) 44:3 Limnology and Oceanography 716-720; Phil Renforth and Gideon Henderson, "Accessing Ocean Alkalinity for Carbon Sequestration: Ocean Alkalinity for C Sequestration" (2017) 55:3 Reviews of Geophysics 636-674 at 665-666.
[200] GESAMP *supra* note 53 at 67.
[201] Ibid.
[202] Ibid.
[203] Ibid.
[204] Ibid.
[205] Ibid.
[206] GESAMP *supra* note 53 at 67.

2.3.6 Methane Capture and Destruction/Degradation

There are suggestions to extract methane trapped in sediments beneath the sea.[207] Methane found in sediment beneath the sea is created by the decomposition of organic carbon and then travels through water-laden sediment.[208] At an appropriate condition, the methane combines with water to form methane gas hydrate[209] which remains stable at high pressures and low temperatures in sediments beneath the seabed.[210]

There is a limited amount of information about the mitigation and capture of methane.[211] Salter is the first author to publish information proposing a means to capture methane released from seabed sediment from the arctic seabed.[212] Subsequently, Lockley[213] and Stolaroff et al.[214] published the ways to mitigate and capture methane. Lockley suggested the mixing of water masses to promote bubble dissolution by extending the mean bubble path and altering the methane partial pressure of surrounding water.[215] Stolaroff et al. considered capturing methane and flaring it or recovering it.[216]

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[207] Ponnivalavan Babu et al., "Methane Production from Natural Gas Hydrates via Carbon Dioxide Fixation" (2014) 61 Energy Procedia 1776-1779; Geir Ersland et al., "Transport and Storage of CO2 in Natural Gas Hydrate Reservoirs" (2009) 1:1 Energy Procedia 3477-3484; Naval Goel, "In Situ Methane Hydrate Dissociation With Carbon Dioxide Sequestration: Current Knowledge and Issues" (2006) 15:3-4 Journal of Petroleum Science and Engineering 169-184; Youngjune Park et al., "Sequestering Carbon Dioxide into Complex Structures of Naturally Occurring Gas Hydrates" (2006) 103:34 Proceedings of the National Academy of Sciences 12690-12694.
[208] Y. C. Beaudoin, et al., "Frozen Heat: A UNEP Global Outlook on Methane Gas Hydrates" (2014) United Nations Environment Programme, GRID-Arendal. Available at: https://www.netl.doe.gov/sites/default/files/netl-file/gas-hydrate-global-assessment-executive-summary%5B1%5D.pdf; GESAMP *supra* note 53 at 67.
[209] Ibid.
[210] GESAMP, *supra* note 53 at 67.
[211] Ibid., 67.
[212] Stephen H. Salter, "Can We Capture Methane from the Artic Seabed?" (16 October 2011), online: http://arctic-news.blogspot.com/p/methane-capture.html.
[213] Andrew Lockley, "Comment on "Review of Methane Mitigation Technologies with Application to Rapid Release of Methane from the Arctic"" (2012) 46:24 Environmental Science & Technology 13552-13553. Available at: https://pubs.acs.org/doi/10.1021/es303074j.
[214] Joshuah K. Stolaroff et al., "Review of Methane Mitigation Technologies with Application to Rapid Release of Methane from the Arctic" (2012) 46:12 Environmental Science & Technology 6455-6469. Available at: https://pubs.acs.org/doi/10.1021/es204686w.
[215] Andrew Lockley, *supra* note 213.
[216] Joshuah K. Stolaroff et al, *supra* note 214.

Methane is a potent greenhouse gas with a high degree of global warming potential.[217] There are concerns among scientists and groups regarding the release of a significant amount of methane from the Arctic due to the higher global warming potential of methane.[218] This implies that this technique must institute sufficient mechanisms to capture methane and degrade (flare) it with concomitant carbon dioxide release to reduce the additional warming of the atmosphere from methane release. Some scientists do not believe that there is a high possibility of substantial methane discharges from Arctic sediments at a large scale.[219]

2.3.7 Increasing Ocean Reflectivity

The ocean can counteract global warming by reflecting sunlight into space.[220] This technique introduces reflective materials at the surface layer of the ocean to reflect solar radiation into space.[221] It is estimated that the ocean ordinarily reflects about 5% of the sunlight reaching its surface through surface reflection and scattering from the ocean's interior.[222] The National Research Council suggests that increasing the reflectivity of the surface ocean could alter the Earth's radiation balance, resulting in the reflection of more sunlight into space.[223]

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[217] Natalia Shakhova et al., "Extensive Methane Venting to the Atmosphere from Sediments of the East Siberian Arctic Shelf" (2010) 327:5970 Science 1246-1250.

[218] Natalia Shakhova et al., *ibid*; Gail Whiteman et al., "Methane Released by Melting Permafrost Will have Global Impacts that Must be Better modelled" (2013) 499 Nature 401-403; Andrew Glikson, "The Methane Time Bomb" (2018) 146 Energy Procedia 23-29.

[219] David Archer et al., "Ocean Methane Hydrates as a Slow Tipping Point in the Global Carbon Cycle" (2009) 106:49 Proceedings of the National Academy of Sciences 20596-20601 at 20596; John W. Pohlman et al., "Enhanced CO2 Uptake at a Shallow Arctic Ocean Seep Field Overwhelms the Positive Warming Potential of Emitted Methane" (2017) 114:21 Proceedings of the National Academy of Sciences 5355-5360; Carolyn D. Ruppel and John D. Kessier, "The Interaction of Climate Change and methane Hydrates" (2017) 55:1 Reviews of Geophysics 126-168.

[220] National Research Council, *supra* note 161.

[221] GESAMP *supra* note 53 at 70.

[222] Ibid., 69.

[223] National Research Council, *supra* note 161.

There are several methods of increasing the ocean's reflectivity, and these include microbubbles, foams, ice, reflective algal blooms, and other reflective materials.[224]

Microbubbles

Microbubbles could enhance the reflectivity of surface and inland waters to help reduce global warming. Seitz proposes that bubble injection into the ocean could increase the albedo effects of the ocean and inland waters and, in the process, counteract climate change.[225] This technique of increasing ocean reflectivity can avoid the risks of introducing reflective materials which are capable of adversely impacting the marine environment.[226] Furthermore, microbubbles could be created at strategic locations, such as the tropics, to have localized cooling effects.[227] Alternatively, specialized commercial or purpose-built ships or bubble generators that generate long-lasting microbubbles, could be used for this purpose.[228]

Reflective foams

Reflective foams can reflect sunlight into space and counteract climate change. Evans et al. suggest that producing reflective foams represents a simple, environmentally friendly approach to increasing the ocean's reflectivity. In this regard, there are two approaches: (i) manufacturing rafts of ephemeral bubbles that would reflect sunlight; and (ii) widespread production of stable foams that would reflect sunlight directly from the ocean surface. The region of the ocean

224 Ibid., 69.
225 Russell Seitz, "Bright Water: Hydrosols, Water Conservation and Climate Change" (2011) 105:3-5 Climate Change 365-381 at 365-368.
226 Ibid.
227 Ibid.; Julia A. Crook et al., "Can Increasing Albedo of. Existing Ship Wakes Reduce Climate Change?" (2016) 121:4 Journal of Geophysical Research: Atmospheres 1549-1558 at 1549 to 1550; J. R. G. Evans et al., "Can Oceanic Foams Limit Global Warming" (2010) 42:2 Climate Research 155-160 at 156-157.
228 Ibid.

identified as suitable for deploying this technique is the High-Nutrient Low-Chlorophyll (HNLC) region of the oceans.[229]

Ocean ice

Ocean ice can enhance the albedo effect of the ocean. The Arctic has been identified as a location to carry out this experiment.[230] Desch et al propose to enhance Arctic ice formation by using wind power during the winter to pump water to the surface to increase the thickness of Arctic ice by about 1 meter.[231]

Reflective algal blooms

Reflective algal blooms of some phytoplankton, such as coccolithophores, can enhance the reflectivity of the ocean.[232] Coccolithophores can enhance the reflectivity of the surface ocean through light scattering.[233] These algal blooms contain dimethyl sulfide which is capable of altering cloud reflectance.[234] Ocean fertilization could stimulate these algal blooms or phytoplankton.[235] Nevertheless, there is no evidence of any specific proposal to enhance reflective algal blooms in the permanent record.[236]

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[229] Alex Aziz et al., "Long-term Stabilization of Reflective Foams in Sea Water" (2014) 4:95 Advances 5328-5336. at 5328.
[230] Steven J. Desch et al., "Arctic Ice Management" (2016) 5:1 Earth's Future 107-127 at 109.
[231] Ibid.; GESAMP, *supra* note 53 at 70; L. Field et al., "Increasing Arctic Sea Ice Albedo Using Localized Reversible Geoengineering" (2018) 6:6 Earth's Future 882-901.
[232] P. M. Holligan et al., "A Biogeochemical Study of the Coccolithophore Emiliania Huxleyi, in the North Atlantic" (1993) 7:4 Global Biogeochemical Cycles 879-900.
[233] Ibid.
[234] Robert J. Charlson et al., "Oceanic Phytoplankton, Atmospheric Sulphur, Cloud Albedo and Climate" (1987) 326 Nature 655-661 at 655; P. K. Quinn and T. S. Bates, "The Case Against Climate Regulation via Oceanic Phytoplankton Sulphur Emissions" (2011) 480 Nature 51-56.
[235] GESAMP, *supra* note 53 at 70.
[236] Ibid., 71.

There are direct and indirect impacts on the environment in enhancing ocean reflectively.[237] With regards to the indirect impact on the climate system, it could alter the distribution of temperature and precipitation, and the potential for biologically mediated changes in the ocean sink for atmosphere.[238]

The long-lasting microbubbles or foams often contain surfactants or other stabilizing materials which could indirectly and adversely impact the marine environment. The adverse impacts of the microbubbles or foams on the ocean includes reducing phytoplankton production of dimethyl sulphide,[239] and causing complex influences on carbon cycle expected from interactions of bubbles, foams and surfactants with existing organic constituents of surface waters.[240] It also impacts on ocean chemistry[241] and increases the acidity of the ocean because of the increase in cooler surface water absorbing carbon dioxide.[242] It impacts on the biota due to the chemical interactions with micro-plastics,[243] and the interactions between surfactants, bubbles and foams with the sea-surface ecosystem including microbes, larvae, turtles, marine mammals and sea-birds,[244] impacts on fisheries and fishing.[245] Additionally, aquaculture sites, coastal areas and beaches could be impacted by foams accumulating.[246]

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[237] Ibid.
[238] Ibid., 72.
[239] Ibid., 72.
[240] Xavier Mari et al., "Transport Exopolymer Particles: Effects on Carbon Cycling in the Ocean" (2017) 151 Progress in Oceanography 13-37; GESAMP, *ibid* at 72.
[241] GESAMP, *ibid* at 72.
[242] Ibid., 72.
[243] Kara Lavender Law and Richard C. Thompson, "Microplastics in the Sea" (2014) 345:6193 Science 144-145.
[244] GESAMP *supra* note 53 at 72.
[245] Ibid., 72.
[246] Ibid., 72.

Moreover, there are in direct impacts of ocean reflectivity on the ocean. The direct impact of increasing the ocean's reflectivity is that the introduction of microbubbles could affect vertical mixing in the ocean, changes in ocean circulation, photosynthesis, and risks to the biosphere.[247]

2.3.8 Marine Cloud Brightening

Marine cloud brightening could enhance the reflectivity of ocean clouds.[248] Latham is credited with being the first to propose this technique.[249] The rationale behind this technique is to seed marine stratocumulus clouds with sub-micrometer seawater particles to enhance the cloud albedo through the formation of the water droplets, in the process the clouds become denser and more reflective.[250] Experts note that marine cloud brightening technique explores the Twomey effects where abundant smaller cloud droplets, rather than fewer larger cloud droplets to reflect sunlight more effectively.[251] The technique does not store carbon in the ocean, it cools the surface ocean, thus enhancing the capacity of the ocean to absorb more carbon dioxide.[252]

The technique could cool the surface temperature of the planet, as well as reduce cyclones.[253] The National Research Council argues that the implementation of marine cloud brightening at a large scale could offset anthropogenic warming.[254] Latham et al. argue that this

[247] Alan Robock, "Bubble, Bubble, Toil and Trouble: An Editorial Comment" (2011) 105:3-4 Climate Change 383-385.
[248] John Latham et al., "Marine Cloud Brightening" (2012) 370:1974 Mathematical, Physical, and Engineering Sciences 4217-4262. [John Latham et al., "Marine Cloud Brightening"].
[249] John Latham, "Control of Global Warming" (1990) 347 Nature 339-340.
[250] GESAMP *supra* note 53 at 73. Latham et al. encouraged the technique to be executed particularly in the north-eastern or south-eastern tropical Pacific, where marine stratocumulus clouds often form. See John Latham et al., Marine Cloud Brightening, *supra* note 248.
[251] GESAMP, *supra* note 53 at 73.
[252] Ibid., 74.
[253] John Latham et al., Marine Cloud Brightening, *supra* note 248.
[254] National Research Council, *Climate Intervention: Reflecting Sunlight to Cool the Earth* (The National Academies Press, 2015b), online: https://nap.nationalacademies.org/read/18988/chapter/1.

technique could significantly lower sea surface temperature and thereby diminish the energy available to tropical cyclones.[255]

A handful of processes are under consideration. Latham et al. and Salter et al. argue that using aircraft to undertake this technique is efficient because it offers significant environmental and cost-saving benefits.[256] However, where the technique uses vessels, Salter et al. described the design and operation of any vessel in this regard and stated that it was better to have a fleet of vessels dedicated to the task of cloud seeding.[257]

Marine cloud brightening techniques could adversely impact the marine environment. The implementation of this technique could significantly decrease the sea surface temperature and affect photosynthesis in the oceans.[258] It could also lead to changes in upwelling and mixing, as well as affect ecosystem services.[259] Also, by reducing sea surface temperature, the technique could influence primary productivity, restructure the vertical structure of the water column, and modify the food webs and biogeochemical cycles, with influences on carbon storage that are not readily predicted.[260]

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[255] John Latham et al., Marine Cloud Brightening, *supra* note 248; John Latham et al., "Marine Cloud Brightening: Regional Applications" (2014) 372:2031 Mathematical, Physical, and Engineering Sciences 20140053.
[256] John Latham et al., "Global Temperature Stabilization via Controlled Albedo Enhancement of Low-Level Maritime Clouds" (2008) 366:1882 Mathematical, Physical, and Engineering Sciences 2969-3987; Stephen Salter et al., "Sea-going Hardware for the Cloud Albedo Method of Reversing Global Warming" (2008) 366:1882 Mathematical, Physical, and Engineering Sciences 3989-4000.
[257] Stephen Salter et al., ibid.
[258] GESAMP, supra note 53 at 74.
[259] National Research Council, 2015b, *supra* note 254.
[260] E. Baughman et al., "Investigation of the Surface and Circulation Impacts of Cloud-Brightening Geoengineering" (2012) 25:21 Journal of Climate 7527-7543; Nick J. Hardman-Mountford et al., "Impacts of Light Shading and nutrient Enrichment Geoengineering Approaches on the Productivity of a Stratified, Oligotrophic Ocean Ecosystem" (2013) 10:89 Journal of the Royal Society Interface 20130701-20130701; K. Siv Lauvset et al., "Climate Engineering and the Ocean: Effects on Biogeochemistry and Primary Production" (2017) 14:24 Biogeochemistry 5675-5691 at 5687; Antti-llari Partanen et al., "Direct and Indirect Effects of Sea Spray Geoengineering and the Role of Injected Particles Size: Sea Spray Geoengineering" (2012) 117:D2 Journal of Geophysical Research: Atmosphere 1-17.

2.3.9 Ocean Thermal Energy Conversion (OTEC)

OTEC uses temperature differentiation in the ocean to generate electricity.[261] According to GESAMP, the OTEC concept existed about 140 years ago.[262] The surface ocean water is warmer than the deep layers of the ocean.[263] OTEC explores the difference in temperature between the surface seawater and ocean interior to generate electricity.[264] The warm surface water is used to vaporize a working fluid with a low boiling point, such as ammonia, in the process using the vapor to drive a turbine and generator.[265] The cold water from the ocean interior is used to recondense the working fluid.[266]

OTEC serves many purposes, including geoengineering purposes. The electricity generated using OTEC could power the electrical grid or produce hydrogen fuels.[267] OTEC was originally not developed for geoengineering purposes. However, the principles and engineering approaches could be occasionally adapted and applied as thermodynamic or heat pipe geoengineering to cool ocean surface waters as a by-product of OTEC or without generating electricity.[268]

Researchers have earmarked a handful as deployment zones for OTEC. The technology has the most significant potential efficacy in tropical regions, and the ideal locations for its deployment are regions where deep ocean water is near the shore.[269] Hawaii, Okinawa (Japan), and Tamil Nadu (India) are locations where researchers have tested OTEC.[270] In addition, the

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261 GESAMP *supra* note 53 at 75.
262 Ibid., 75.
263 Ibid.
264 Ibid.
265 Ibid.
266 Ibid.
267 Greg H. Rau and Jim R. Baird, "Negative-CO2-Emissions Ocean Thermal Energy" (2018) 95 Renewable and Sustainable Energy Reviews 265-272.
268 GESAMP *supra* note 53 at 75.
269 Ibid.
270 Ibid.

Caribbean Sea, the Gulf of Guinea, the Gulf of Mexico, the Northern Indian Ocean, the northern coast of Australia, and the Islands in the South China Sea are suitable geographic properties for OTEC.[271]

In many ways, OTEC could adversely impact the marine environment. The technology has the potential to worsen the climate problem by discharging excessive amounts of carbon and nutrients at the surface of the ocean, potentially causing shifts in community-specific composition, enhancing the growth of phytoplankton, or causing the growth of algal blooms.[272] It could also result in the impingement of fish and entrainment of plankton and other tiny organisms at the surface and interior of the ocean. The use of pipes in OTEC, along with the noise and vibrations generated during the technology's operation, could have physical and biological effects on fish and other species, such as interfering with communication or predator/prey dynamics.[273] Also, structures deployed in the oceans get covered by fouling organisms and in the process serve as artificial reefs that attract fish. It could result in ecosystem changes should OTEC be deployed at a large scale.[274] Furthermore, large-scale deployment of OTEC heat pipes for purposes of thermodynamic geoengineering could adversely impact the marine environment as it would decrease the regional sea surface temperature while having all the same localized environmental impacts as conventional OTEC.[275]

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[271] Shylesh Muralidharan, "Assessment of Ocean Thermal Energy Conversion", (2012) MSc Thesis, Massachusetts Institute of Technology, online: http://dspace.mit.edu/handle/1721.1/76927#files-area.
[272] Rod Fujita et al., "Revisiting Ocean Thermal Energy Conversion" (2012) 36:2 Marine Policy 463-465; Helen Knight, "Oceans of Power: The Resurrection of Ocean Thermal" (2014) 221:2958 New Scientist 48-51.
[273] Shylesh Muralidharan, *supra* note 271 at 93.
[274] GESAMP *supra* note 53 at 76.
[275] Ibid., 76.

2.3.10 Deep Water Source Cooling or Sea Water Air Conditioning

This technique does not sequester carbon but uses cold deep ocean water to cool temperatures in buildings.[276] The technique uses cold seawater from depths down to around 1,000m to cool buildings,[277] particularly in tropical areas.[278] So far, the technique has been deployed with deep lake water for locations in Toronto, Stockholm and at Cornell University in Ithaca, New York.[279]

The technique can be deployed in many oceanic islands and mainland locations where the continental shelf could be narrower or nonexistent. In this regard, locations such as Halifax (Canada), Hawaii, Bora Bora, Reunion Island (Indian Ocean), Pyeongchang (Republic of Korea), Hong Kong, and Curacao are possible.[280]

Deep water source cooling or seawater air conditioning can contribute to climate change. Like artificial upwelling and OTEC, this technique releases carbon and nutrients at the surface seawater that could have a significant impact on the marine environment, including a shift in community species composition, enhanced phytoplankton growth, or result in algal blooms.[281]

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[276] Christopher Pala, "Honolulu to Implement Cooling with Deep-Sea Water: System, to go On-line in 2012, is Designed to Reduce Costs and Greenhouse Gas Emissions" (2009) 44:1 Environmental Science & Technology 13-13.

[277] In Pyeongchang, Republic of Korea, this technique was employed to cool the ice rink at the 2018 Winter Olympics. See GESAMP *supra* note 53 at 77.

[278] Christopher Pala, *supra* note 276.

[279] Christopher M. Looney and Stephen K. Oney, "Seawater District Cooling and Lake Source District Cooling" (2007) 104:5 Energy Engineering 34-45 at 40; Lenore Newman and Yuill Herbert, "The Use of Deep Water Cooling Systems: Two Canadian Examples" (2009) 34:3 Renewable Energy 727-730.

[280] GESAMP *supra* note 53 at 77.

[281] Rod Fujita et al., *supra* note 272; Helen Knight, *supra* note 272.

CHAPTER THREE: MARINE GEOENGINEERING: THE ROLE OF GLOBAL MULTILATERAL INTERNATIONAL AGREEMENT IN REGULATING MARINE GEOENGINEERING

This Chapter discusses the obligations created by multilateral environmental agreements relevant to governing geoengineering activities at sea. The provisions of these multilateral environmental agreements or resolutions adopted by the Contracting Parties to these agreements create these obligations. In some instances, these obligations have metamorphosized into customary international law, thereby applicable to all nations. It will become apparent that the governance of this technique at the global level has evolved. In some instances, conventions use amendments to promote the governance of marine geoengineering.

The UNCLOS remains one of the widely adopted international instruments, and it plays a crucial role in governing marine geoengineering activities. It establishes obligations that apply to geoengineering activities in the ocean. Some of these obligations have attained the status of customary international law; therefore, they apply to non-party States. The following parts discuss the general obligations created by the UNCLOS and how they apply to marine geoengineering.

3.1 Marine Geoengineering Governance by the United Nations Convention on the Law of the Seas (UNCLOS).

The UNCLOS remains one of the widely adopted international instruments, and it plays a key role in governing marine geoengineering activities. It establishes obligations which apply to geoengineering activities in the ocean. Some of these obligations have attained the status of customary international law, therefore they apply to non-party States. The next parts discuss the general obligations created by the UNCLOS and how they apply to marine geoengineering.

3.1.1 The Role of Coastal States in Superintending Over Marine Geoengineering

The UNCLOS establishes an international legal regime that governs all uses of the ocean and its resources.[282] It establishes "… a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources".[283] It addresses a wide range of issues including introducing new legal concepts and regimes and addresses emerging concerns about the ocean.[284] It is also capable of addressing issues affecting the ocean including environmental control, marine scientific research, economic and commercial activities, and dispute resolution.[285]

The Convention establishes different maritime jurisdictional zones. Firstly, it establishes baselines[286] that separate a coastal state's land territory from its maritime territory.[287] The normal baseline is used where there is a low-water line along the coast as marked on large-scale charts officially recognized by the coastal States.[288] Whereas, the straight baseline is used in places where the coastline is deeply indented and cut into, or there is a fringe of islands along the coast

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[282] International Maritime Organization (IMO), "United Nations Convention on the Law of the Sea". Available at: https://www.imo.org/en/ourwork/legal/pages/unitednationsconventiononthelawofthesea.aspx#:~:text=The%20United%20Nations%20Convention%20on,the%20oceans%20and%20their%20resources.
[283] Ibid.
[284] Ibid.
[285] Elizabeth F. Quinby, "Regulating Geoengineering: Application of GMO Trade and Ocean Dumping Regulation" (2018) 51:1 Vanderbilt Journal of Transnational Law 211 at 227.
[286] The normal baseline and straight baseline.
[287] Elise Johansen et al., "Law of the Sea Responses to Sea-Level Rise and Threatened Maritime Entitlements: Applying an Exception Rule to Manage an Exception Situation" in *The Law of the Sea and Climate Change* (United Kingdom: Cambridge University Press: 2020) at 312.
[288] UNCLOS, Art. 5.

in its immediate vicinity.[289] Under UNCLOS, the maritime jurisdictional zones comprise internal waters, territorial sea, the exclusive economic zone, and the continental shelf.

Each maritime jurisdictional zone vests specific rights and jurisdiction to each coastal State. In internal waters, Coastal States are at liberty to apply national laws and determine the conditions of entry of foreign vessels.[290] Every Coastal State has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical measures from the baseline. Within the territorial sea, each Coastal State can apply its domestic laws and can regulate environmental pollution.[291] Foreign vessels enjoy a right to innocent passage within the territorial seas subject to avoiding environmental pollution.[292] The Exclusive Economic Zone (EEZ) extends up to 200 nautical miles from the baseline of the Territorial Sea.[293] In the EEZ, all Coastal States have sovereign rights over natural (living and mineral) resources, and jurisdiction to protect and preserve the marine environment.[294] The continental shelf comprises 'the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth if the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.'[295] All Coastal States have exclusive rights to exploit natural resources within their continental shelf.[296] They also have

[289] UNCLOS, Art. 7.
[290] Military and Paramilitary Activities and Against Nicaragua (Nicaragua v United States of America), [1986] ICJ Rep 14, para. 212 and 213.
[291] UNCLOS, Art. 2(3).
[292] UNCLOS, Art. 17.
[293] UNCLOS, Art. 57.
[294] UNCLOS, Art. 58
[295] UNCLOS, Art. 76(1).
[296] UNCLOS, Art. 77.

jurisdiction to protect and preserve the marine environment within the continental shelf against pollution.[297]

The rights enjoyed by Coastal States are not absolute to warrant the wanton use of pipes in the ocean for techniques such as ocean upwelling. Pursuant to article 225 of the UNCLOS, States are under an obligation to avoid endangering the safety of navigation, create any hazard to a vessel, or expose the marine environment to an unreasonable risk.[298] Thus, any marine geoengineering technique which is likely to pose as a danger to navigation, causes any hazard to a vessel, or increases the risk of danger to navigation is contrary to the aims of the UNCLOS.

3.1.2 UNCLOS Obligations on States and their Utility in Governing Marine Geoengineering

UNCLOS imposes a general obligation on States to protect and preserve the ocean.[299] Part XII of UNCLOS imposes a general obligation on all State Parties to protect and preserve the marine environment.[300] According to McConnell et al., Part XII is constitutional as it reflects, to an extent, existing customary international law as well as spells out the first comprehensive statement on the protection and preservation of the marine environment in international law.[301] Article 192 of the UNCLOS establishes the general obligation on all States to protect and preserve the marine environment.[302] The implementation of article 192 is based on two key

[297] UNCLOS, Art. 208.
[298] UNCLOS, Art. 225.
[299] UNCLOS, Part XII.
[300] Ibid.
[301] M. L. McConnell et al., "The Modern Law of the Sea: Framework for the Protection and Preservation of the Marine Environment?" (1991): 83 Case W. Res. J. Int'l L. 23, at 84; Jonathan. L. Hafetz, "Fostering Protection of the Marine Environment and Economic Development: Article 121(3) of the Third Law of the Sea Convention," (2000) 15:3 American University International Law Review 583 at 597; Martin H. Belsk, "The Ecosystem Model Mandate for a Comprehensive United States Ocean Policy and Law of the Sea" (1989) 26:3 The San Diego Law Review 417.
[302] Ibid., Art. 192.

factors;[303] the regulatory measures instituted to govern various aspects of human activities at sea, and the efficacy of the established enforcement measures applicable to different areas of the ocean.[304]

The obligation to protect and preserve the marine environment must take into consideration considering the rights and duties of States under the UNCLOS and other related international conventions.[305] The general obligation under article 192 must be weighed against the rights of State Parties to exploit their natural resources according to article 193.[306] According to Hafetz, articles 192 and 193 are binding on all States Parties under UNCLOS and all States – that is, both parties and non-parties to UNCLOS – under customary international law.[307] All States accept as binding customary international law an obligation to rationally and equitably use their resources,[308] as well as prevent harm to the environment and resources.[309] Unlike Principle 21 of Stockholm Declaration[310] and Principle 2 of Rio Declaration,[311] a country's right to exploit its natural resources is subject to the "duty to protect and preserve the marine environment" by UNCLOS. Thus, States should weigh the right to exploit their natural resources within their jurisdiction against the general obligation to protect and preserve the marine environment.[312]

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303 Robin Warner, "Marine Snow Storms: Assessing the Environmental Risks of Ocean Fertilization" (2009) 2009:4 Carbon & Climate Law Review 426 at 429.
304 Ibid.
305 Ibid.
306 Meinhard Doelle, "Climate Change and the Use of the Dispute Settlement Regime of the Law of the Sea Convention" (2006) 37:3-4 Ocean Development and International Law 319-337 at 323.
307 Jonathan. L. Hafetz, *supra* note 6 at 301.
308 Gunther Handl, "National Uses of Transboundary Air Resources: The International Entitlement Issue Reconsidered" (1986) 26:3 National Resources Journal 405-467; Gunther Handl, "The Principle of Equitable Use as Applied to Internationally Shared Natural Resources: Its Role in Resolving Potential International Disputes Over Transfrontier Pollution" (1978) 14:1 Revue Belge de Droit International/Belgian Review of International Law 40 at 44.
309 See Trail smelter case (United States, Canada) (1905 – 1982) VOL. III Reports of International Arbitral Awards at 77; Martin H. Belsk, *supra* note 301 at 458.
310 Stockholm Declaration of the United Nations Conference on the Human Environment (1972) 11 International Legal Materials 1416, principle 2. [Stockholm Declaration].
311 Declaration of the United Nations Conference on Environment and Development, UN Doc. A/CONF.151/26, (1992) 31 *International Legal Materials 874* (Rio Declaration).
312 Elizabeth F. Quinby, *supra* note 285 at 227.

All States must take measures to prevent, reduce and control pollution of the marine environment.[313] The obligation to prevent and reduce pollution applies to marine geoengineering proposals that introduce substances into the marine environment.[314] According to Meinhard Doelle article 194 is focal to any analysis involving the mitigation of climate change under UNCLOS as it lays the foundation for specific obligations that gives further guidance on the obligations of a State to protect and preserve the marine environment.[315] In Meinhard Doelle's view the specific obligations on State Parties in this regard comprise of:[316]

- an obligation for States to act individually or jointly as appropriate;[317]
- an obligation to take all measures necessary to prevent, reduce, and control pollution of the marine environment;[318]
- an obligation for states to use the best practical means available;[319]
- an obligation for States to act in by their capabilities;[320]
- an obligation to endeavor to harmonize policies with other States;[321]
- an obligation for States to control activities under their control or jurisdiction to not cause damage by pollution to other States and their environment;[322]

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313 UNCLOS, Art. 194.
314 Karen N. Scott, "Geoengineering and the Marine Environment" in Rosemary Rayfuse, ed, Research Handbook on International Marine Environmental Law (Cheltenham, UK: Edward Elgar, 2015) 451. [Karen N. Scott, "Geoengineering and the Marine Environment"]; Kerryn Brent., "Marine Geoengineering Governance and the Importance of Compatibility with the Law of the Sea" in *Research Handbook on Climate Change, Oceans and Coasts* (United Kingdom: Edward Elgar Publishing Limited, 2020), at 452.
315 Ibid., 323.
316 Ibid.
317 UNCLOS, Art. 197, 207(4) and 212(3).
318 Ibid., Art. 194(1). According to Meinhard Doelle, *pollution* includes adding energy to the marine environment. See Meinhard Doelle, *supra* note 306.
319 UNCLOS, *supra* note 5, Art. 194(1).
320 Ibid.
321 Ibid.
322 Ibid., Art. 194(2).

- an obligation to prevent pollution from spreading to areas outside of a state's jurisdiction or control;[323] and
- a specific obligation for the preservation and protection of rare or fragile ecosystems and the habitats of species at risk.[324]

Thus, any approval of marine geoengineering techniques by a State following its obligation to prevent, reduce and control marine environment pollution must cater to other specific obligations, including those outlined by Meinhard above.

Furthermore, the obligations owed in this regard turn in part on the definition of marine pollution under UNCLOS.[325] The Convention's inclusion of the harm to water quality and fisheries expands the earlier definition presented in the 1974 Paris Convention to cover the storage of atmospheric carbon dioxide in the ocean.[326] According to David L. VanderZwaag, Article 1(4) is sufficient to cover the sequestration of carbon into the ocean.[327] Additionally, article 194 fortifies the broad definition of marine pollution[328] and emphasizes the need to protect and preserve rare or fragile ecosystems, and the habitat of depleted, threatened, or endangered

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[323] Ibid.
[324] Ibid., Art. 194(1), (2), and (5).
[325] Ibid., Art. 1(4). According to article 1(4), pollution refers to "the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for the use of seawater and reduction of amenities.
[326] Rachel Zajacek, "The Development of Measures to Protect the Marine Environment from Land-Based Pollution: The Effectiveness of the Great Barrier Reef Marine Park Authority in Managing the Effects of Tourism on the Marine Environment" (1996) 3 James Cook University Law Review 64-92 at 74; Convention for the Prevention of Marine Pollution from Land-Based Sources, 4 June 1974, 1546 U.N.T.S 103 (entered into force 6 May 1978).
[327] David L. VanderZwaag, "Ocean Acidification and Geoengineering: Navigating Beyond the Law of the Sea" (2014) 47:1 Rev BDI 137 at 142.
[328] It mandates States to take "… all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source, using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavor to harmonize their policies in this connection." See UNCLOS, Art. 194(1).

species and other forms of marine life.[329] The obligation to protect and preserve the marine environment covers the conservation of living resources of the sea.[330]

Contracting States are required to adopt legislations and measures on dumping which match up to international standards. The UNCLOS defines dumping as any "deliberate disposal of wastes or other matter from vessels… at sea."[331] It also imposes a general obligation on Contracting States to adopt domestic laws and regulations to prevent, reduce and control pollution by dumping[332] and ensure that these legislation and measures are no less effective in preventing, reducing and controlling pollution by dumping than the global rules and standards.[333] It is unclear whether the London Convention rather than the London Protocol constitutes the applicable global rules and standards.[334] Nevertheless, Karen N. Scott argues that the London Convention represents the "global rules and standards" in this context.[335]

By employing a holistic approach, the UNCLOS is comprehensive, progressive, and holistic[336] and relevant in the governance of marine geoengineering. For instance, article 195 calls on States to ensure that in fulfilling their obligations to take measures to prevent, reduce, and control pollution of the marine environment, they must ensure that their activities do not transfer harm from one area to another.[337] Meinhard Doelle argues that while the scope of this

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[329] See UNCLOS, Art. 194(5).
[330] The Southern Bluefin Tuna cases (New Zealand v. Japan; Australia v. Japan), Provisional Measures, 27 August 1999, ITLOS Reports 1999, p. 295, para 120; Chago Marine Protected Area Arbitration (Mauritius v United Kingdom) [2015] para 238, available at: https://pca-cpa.org/en/cases/11/.
[331] UNCLOS, Art 1(5); David Freestone & Rosemary Rayfuse, "Ocean Iron Fertilization and International Law", (2008) 364 Marine Ecology Progress Series 227-234 at 229.
[332] UNCLOS, Art 210(1).
[333] Ibid., Art 210(6).
[334] David L. VanderZwaag, "The International Control of Ocean Dumping: Navigating from Permissive to Precautionary Shores" in *Research Handbook on International Marine Environmental Law* (Northampton: Edward Elgar Publishing, 2015) at 132.
[335] Karen N. Scott, "Regulating Ocean Fertilization under International Law: The Risks" (2013) 2013:2 CCLR 108 at 113.
[336] Jonathan I. Charney, "The Marine Environment and the 1982 United Nations Convention on the Law of the Sea" (1994) 28:4 The International Lawyer 879-901 at 887 and 888.
[337] UNCLOS, Art. 195.

provision remains unclear, it nevertheless introduces the idea that mitigation measures must be such that they do not cause other environmental damage.[338] Likewise, article 196 mandates States to take measures to prevent, reduce and control pollution of the marine environment arising from the use of technologies which may significantly impact the marine environment.[339] Also, article 206 imposes an obligation on States to assess and report the potential effects of activities which may cause substantial pollution or harmful changes to the marine environment.[340] Thus, Contracting States are expected to conduct an environmental impact assessment prior to undertaking marine geoengineering activities offshore.

All States must consider the role of international organizations in effectively governing geoengineering.[341] Article 197 prescribes that States must directly cooperate on a global and regional basis[342] or through competent international organizations such as the IMO to draft international rules, standards, and recommended practice and procedures for the protection and preservation of the marine environment. [343] In the same vein, States are expected to cooperate among themselves or through competent international organizations such as IMO to promote studies, undertake scientific research, and exchange information and data on the pollution of the

[338] Meinhard Doelle, *From Hot Air to Action? Climate Change, Compliance, and the Future of International Environmental Law* (Toronto: Carswell, 2005), at 31 and 43.
[339] UNCLOS, Art. 196(1).
[340] UNCLOS, Art. 206. Besides the UNCLOS, the BBNJ imposes an obligation on States to conduct an environmental impact assessment when it deems a planned activity may cause substantial pollution or significant and harmful changes to the marine environment beyond national jurisdiction. This provision is relevant, particularly to govern marine geoengineering activities that pose transboundary harm to other States and the marine environment. See 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 19 June 2023 C.N.203.2023 (entered into force 20 July 2023), Art. 21.
[341] UNCLOS, Art. 197.
[342] The Baltic Marine Environment Protection Commission (HELCOM)and OSPAR Commission fulfill this obligation as the research outlines these regional institutions' roles to protect and preserve the marine environment within the Baltic Sea and the North-East Atlantic.
[343] UNCLOS, Art. 197. The obligation to cooperate is "… a fundamental principle in the prevention of pollution of the marine environment under Part XII of the Convention and general international law." See MOX Plant (Ireland v. United Kingdom), Provisional Measures, Order of 3 December 2001, ITLOS Reports 2001, p. 95, para. 82.

marine environment.[344] Robin Warner argues that the International Maritime Organization (IMO) and diplomatic conferences are examples of competent international organizations referred to under article 197.[345]

The obligations imposed by the Convention on scientific research apply to marine geoengineering experiments. The starting point is that all States have the liberty to undertake marine scientific research according to UNCLOS.[346] However, the Convention does not define "marine scientific research" but requires all research to "be conducted in compliance with all relevant regulations adopted in conformity" with UNCLOS.[347] Philomene A. Verlaan argues that the overarching obligation of States under UNCLOS to protect and preserve the environment under article 192 includes the obligation to ensure that marine scientific research in any part of the sea complies with marine environment protection provisions of UNCLOS.[348] Parties to the Convention and flag States must have due regard for the sovereign rights of Coastal States' resources within the continental shelf when conducting geoengineering activities in the high seas above a continental shelf.[349]

The obligation of all States to avoid transboundary harm by pollution applies to marine geoengineering activities. The duty to avoid transboundary harm has attained the status of

[344] UNCLOS, Art. 200.
[345] Robin Warner, *supra* note 303, at 430.
[346] UNCLOS, Art. 238.
[347] UNCLOS, Art. 240(d). Moreover, States are free to conduct scientific research ON the high seas subject to Part VI on the continental shelf and Part XIII on marine scientific research. Similarly, Articles 256 and 257 present all States with the right to conduct marine scientific research in the area and the water column beyond the limits of the exclusive economic zone. See UNCLOS, Art. 87, 256, and 257.
[348] Philomene A. Verlaan, "Environmental Activities that Intentionally Perturb the Marine Environment: Implications for the Marine Environmental Protection and Marine Scientific Research Provisions of the 1982 United Nations Convention on the Law of the Sea" (2007) 31:2 Marine Policy 210-216 at 211.
[349] Robin Warner, *supra* note 303 at 431. For instance, according to Article 79(2) of UNCLOS, coastal States are restricted from impeding the laying or maintenance of cables and pipelines on the continental shelf.

customary international law and is reflected in the 1972 Stockholm Declaration[350].[351] Pursuant to UNCLOS, State Parties are required to institute measures that will avoid the transfer of pollution from within their jurisdiction or control to other States and areas beyond their maritime jurisdiction such as the high seas.[352] The Convention prescribes measures to institute to prevent transboundary pollution by providing that the measures employed must be designed to thoroughly reduce the release of toxins, harmful or noxious substances into the ocean.[353] Some marine geoengineering techniques use foreign substances including geosynthetic containers and glass capsules in the carbon storage processes.[354] In other instances, nutrients such as nitrogen are used in the stimulation of phytoplankton.[355] The obligation to prevent transboundary harm by pollution equally extends to marine geoengineering which seeks to sequester carbon dioxide – hazardous substance – into the ocean.

Besides the obligations imposed, the Convention provides an enforcement mechanism to comply with its obligations. Coastal States, Flag States, or any State possess unique enforcement powers to address the breach or potential breach of laws and regulations promulgated according to the Convention.[356] All Coastal States are vested with the power to enforce the obligations to prevent, reduce or control marine pollution arising within their territorial seas, exclusive economic zones or continental shelf.[357] Flag States are required to enforce the obligation to vessels or aircraft flying their flag or registered to their country.[358] Also, any State can enforce

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[350] Stockholm Declaration, *supra* note 310, principle 21.
[351] See the case of Legality of the Threat or Use of nuclear weapons, Advisory Opinion of 8 July 1996, [1996] ICJ Rep 226, [29].
[352] UNCLOS, Art. 194(2).
[353] UNCLOS, Art. 194(3).
[354] See, Mark E. Capron et al., *supra* note 116; Tefano Caserini et al., *supra* note 84.
[355] GESAMP, *supra* note 53 at 48-49.
[356] UNCLOS, Art. 216(1).
[357] UNCLOS, Art. 216(1)(a).
[358] UNCLOS, Art. 216(1)(b).

this obligation when it comes to any act of loading waste or other matter in its territory or at its offshore terminal.[359]

Furthermore, the general obligation to prevent and preserve the marine environment has attained the status of customary international law.[360] This implies that the principles and rules of Part XII of UNCLOS – particularly article 192 and 193 - applies to all nations.[361] Where a country has subscribed to the Convention, the obligations will apply under customary international law and according to the doctrine of *pacta sunt servanda*.[362] For non-party States, the use of the words "obligation" and "duty" in article 192 and 193 of UNCLOS underscores the importance of these obligations and a breach of these provisions constitutes a breach of international law.[363]

In essence, UNCLOS obligates States to protect and preserve the marine environment. These obligations are relevant in establishing a governance regime for marine geoengineering. Based on the above, any geoengineering activity which is likely to impact the ocean and sea adversely is inconsistent with the aims of the UNCLOS.[364]

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359 UNCLOS, Art. 216(1)(c).

360 Alan E. Boyle, "Protecting the Marine Environment: Some Problems and Developments in the Law of the `Sea" (1992) 16:2 Marine Policy 79-85.

361 Moira L. McConnell & Edgar Gold, "The Modern Law of the Sea: Framework for the Protection and Preservation of the Marine Environment?" (1991): 83 Case Western Reserve Journal of International Law 83-105 at 99.

362 Vienna Convention on the Law of Treaties, 23 May 1969, 1155 UNTS 331 (entered into force 27 January 1980), Art. 26.

363 For non-party States, the use of the words, "obligation" and "duty" in Articles 192 and 193 of UNCLOS underscores the importance of these obligations, and a breach of these provisions constitutes a breach of international law. See Moira L. McConnell & Edgar Gold, *supra* note 361.

364 Karen N. Scott, "The Day After Tomorrow: Ocean CO2 Sequestration and the Future of Climate Change" (2005) 18:1 Georgetown International Environmental Law Review 57 at 78. [Karen N. Scott, "The Day After Tomorrow"].

3.2 The Governance of Marine Geoengineering by the Climate Change Regimes.

The contribution of geoengineering in achieving the targets of the UNFCCC climate regime remains an ongoing debate. Many analysts recognize the contribution of geoengineering towards achieving the objectives of UNFCCC.[365] The IPCC's Fifth Assessment report notes the vital role that carbon dioxide removal techniques could play in achieving the temperature target set by the regime.[366]

The objective of UNFCCC is to stabilize atmospheric greenhouse gas concentrations. According to Article 2 of UNFCCC, the main objective of the Convention and all other legal instruments adopted by the UNFCCC regime is to stabilize atmospheric greenhouse gas concentrations to a level that prevents dangerous anthropogenic interference with the climate system.[367] This objective does not imply that the UNFCCC or other related instrument adopted by the Conference of Parties (COP) prohibits other measures such as geoengineering intended to prevent global warming,[368] unless these technologies pose a risk to the environment to the extent that they will deemed as “dangerous anthropogenic interference in the climate system”.[369]

Marine geoengineering technologies could reduce atmospheric carbon dioxide concentration and decrease global warming. According to the Subsidiary Body on Scientific and

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365 Elmar Kriegler et al., “Pathways limiting warming to 1.5°C: a tale of turning around in no time?” (2018) 376:2119 Philosophical Transactions of the Royal Society. Series A: Mathematical, Physical, and Engineering Science p.20160457-20160457; Sabine Fuss et al., “Negative emissions—Part 2: Costs, potentials and side effects” (2018) 13:6 Environmental Research Letters at 2; Rob Bellamy, “Incentivize negative emissions responsibly” (2018) 3 Nature Energy 532-534.

366 Ottmar Edenhofer et al., “Climate Change 2014: Mitigation of Climate Change Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change” (2014) at 14–15; Espen Moe & Jo-Kristian S Røttereng, “The post-carbon society: Rethinking the international governance of negative emissions” (2018) 44 Energy Research & Social Science 199.

367 UNFCCC, Art. 2.

368 Subsidiary Body on Scientific Technical and Technological Advice, Regulatory Framework for Climate-Related Geoengineering Relevant to the Convention on Biological Diversity, UNEP/CBD/SBSTTA/16/INF/29 (2 April 2012). Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-29-en.pdf at 31. [Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/29].

369 Ibid.

Technological Advice (SBSTTA), carbon dioxide removal technologies such as ocean fertilization, ocean upwelling, and downwelling would reduce atmospheric greenhouse gas concentration, thereby making them compatible with the object of the Convention.[370] Also, solar radiation management techniques such as marine cloud brightening would contribute to a decrease in global warming.[371]

UNFCCC does not explicitly regulate marine geoengineering. Nevertheless, it contains relevant provisions which govern marine geoengineering.[372] For instance, the obligation to adopt a precautionary approach in addressing issues of climate change per article 3(3) of UNFCCC applies to marine geoengineering.[373] Also, the obligation to enhance and protect carbon sinks and reservoirs under article 4(2)(a) extends to marine geoengineering activities which involve the stimulation of the ocean to capture and store carbon.

The Kyoto Protocol[374] does not permit nor prohibit geoengineering activities.[375] However, its flexible mechanisms are relevant in governing marine geoengineering.[376] Up until now, the Kyoto Protocol's Clean Development Mechanism (CDM) has included carbon capture and storage in geological formation as the only geoengineering mechanism as the eligible option.[377] Marine geoengineering activities such as ocean fertilization are not recognized by the carbon markets.[378]

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370 Ibid.
371 Ibid.
372 Melissa Eick, *supra* note 77 at 362 at 361.
373 UNFCCC, Art. 3(3).
374 See Kyoto Protocol.
375 Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/29, *supra* note 368 at 32.
376 Ibid.
377 Ibid.
378 Elise Johansen, "Ocean Feralization" in *The Law of the Sea and Climate change: Solutions and Constraints* (U.K.: Cambridge University Press, 2020) at 191.

The Paris Agreement does not contain explicit provisions on geoengineering, but it requires the Contracting States to achieve the global average temperature target.[379] The Paris Agreement urges all State Parties to hold the increase in the global average temperature below 2°C above pre-industrial levels and further pursue efforts to limit the temperature to 1.5°C above pre-industrial levels.[380] Presently, the projections estimate that the current Nationally Determined Contribution (NDCs) submitted to the Secretariat by States may result in an increase in the global average temperature of between 2.6°C and 3.7°C by 2100,[381] and a further increase for centuries beyond Holocene climate optimum level for more than 10,000 years.[382] Consequently, geoengineering is regarded as one of the measures that could be used to address the deficit.[383]

Marine geoengineering techniques are inherently risky endeavors, yet they could contribute to counteracting the concentration of atmospheric greenhouse gases. In its Fifth Assessment Report, the IPCC identifies several CDR techniques that could reduce anthropogenic greenhouse gas levels in the atmosphere.[384] However, the report notes that CDR poses potential adverse effects on the environment, such as ocean deoxygenation and surface reflectance depending on the technology involved and the scale of deployment.[385]

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[379] Paris Agreement, Art. 3.

[380] Ibid, Paris Agreement, Art. 2. It is argued that the emission reduction targets set by Parties to the Paris Agreement are inadequate to counteract anthropogenic greenhouse gases. See Willam C. G. Burns, *The Paris Agreement and Climate Geoengineering Governance: The Need for a Human Rights-Based Component* (Ontario: Centre for International Governance Innovation, 2016).

[381] Calum Brown, "Achievement of Paris Climate Goals unlikely due to time lags in the land system" (2019) 9 Nature Climate Change 203 at 206; Rob Bellamy, *supra* note 381; Adrian E Raftery et al., "Less than 2oC warming by 2100 unlikely" (2017) 7 Nature Climate Change 637; Joeri Rogelj et al., "Paris Agreement climate proposals need a boost to keep warming well below 2°C" (2017) 534 Nature 631.

[382] Peter U. Clark et al., "Consequences of Twenty-First Century Policy for Multi-Millennial Climate and Sea-Level Change" (2016) 6 Nature Climate Change 360 at 361.

[383] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2014: Synthesis Report. Contribution of Working Group I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, [P. K. Pachauri and L. A. Meyer (eds.)] (Geneva: World Meteorological Organization, 2014). Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf. [IPCC, Synthesis Report (2014)].

[384] Ibid.

[385] Ibid.

The lack of explicit provisions by the climate change regime under the UNFCCC framework has led to the calls for the negotiation of a new regime capable of regulating marine geoengineering.[386] Due to the absence of explicit provisions to govern geoengineering activities, there have been suggestions to revise and amend the existing UNFCCC climate change regimes or adopt a protocol under the UNFCCC framework to govern geoengineering.[387]

3.3 Governance of Marine Geoengineering under Other Multilateral Environmental Agreements

The CBD plays a significant role in the governance of marine geoengineering. The Conference of Parties to the CBD has contributed immensely to establishing a governance regime for marine geoengineering activities such as ocean fertilization. The following parts will trace the resolutions adopted over the years to govern these activities. Also, it will discuss the contributions of the Subsidiary Body on Scientific and Technological Advice (SBSTTA) towards establishing a governance regime for marine geoengineering.

3.3.1 Governance under the Convention Biological Diversity (CBD)

This Part examines the developments made by the Contracting Parties to the CBD in the governance of marine geoengineering. It also traces the evolution of marine geoengineering governance under the regime and the impacts of multilateral international agreements like the London Convention and London Protocol on the governance of these techniques by the CBD. It also outlines the impacts of climate change on biodiversity in time past to enable the reader to appreciate the risks associated with climate change.

[386] Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/29, *supra* note 368.
[387] Ibid., 31.

For proper context, "biological diversity" and "biodiversity" are interchangeably used in this thesis. Also, the CBD defines "biological diversity" as 'the variability among living organisms from all sources including terrestrial, marine, and other aquatic systems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.'[388]

3.3.1.1 Impact of Climate Change in the Pleistocene Period

History shows that climate change has not spared biological diversity in the past. Past impacts of climate change have been documented to include changes in temperature, precipitation, sea level and extreme climate events during the Pleistocene period.[389] The Pleistocene period was distinguished by extended glacial periods featuring cool climates, typically lasting around 100, 000 years.[390] The glacial periods were intermittently interrupted by shorter interglacial periods, lasting 10,000 to 20,000 years – during which the climate resembled those of the present era.[391] The cause of these glacial and interglacial cycles is attributed to the changes in the seasonal distribution of the sun radiation as a result of the earth's orbit, amplified by snow, ice, vegetation and natural greenhouse gas feedbacks.[392] These changes resulted in the reorganization of society.[393] Kohfeld and Harrison note that during the Pleistocene period, some biomes expanded

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388 Convention on Biological Diversity, Art. 2.
389 Secretariat of the Convention on Biological Diversity, *Linkages Between Biological Diversity and Climate Change: Advice on the Integration of Biological Considerations into the Implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol,* CBD Technical Series No. 10, Montreal, 2003, Available at: https://www.cbd.int/doc/publications/cbd-ts-10.pdf. [Convention on Biological Diversity Secretariat, Technical Series No.10].
390 J. J. Lowe and M. J. C. Walker, *Reconstructing Quaternary Environment* (London: Longman, 1988).
391 Ibid.
392 Convention on Biological Diversity Secretariat, Technical Series No.10, *supra* note 389 at 21.
393 Ibid.

while close temperate and moist tropical forest moved towards the equator and disintegrated.[394] Also, there were periods of rapid global warming resulting in many trees and shrub species migrating to more favorable areas with suitable weather conditions.[395] Jackson and Johnson note that the last global reorientation of society occurred during the Pleistocene period where there was significant extinction of marine organisms in many ocean basins.[396]

The ability of present biological diversity to adjust has been in doubt.[397] Based on the projected rate and magnitude of climate change, scholars have raised doubt about the ability of species to adjust to the potential changes arising out of climate change, especially looking at the control humans have over the landscape.[398] Phenomena such as an increase in temperature beyond 3°C and the astronomical carbon dioxide levels in the atmosphere remain unprecedented or have not been encountered for over millions of years.[399] During the Pleistocene Period, the atmospheric carbon dioxide levels were nowhere near present-day levels, let alone the projected future level.[400]

There is a projection that climate change and an increase in the atmospheric concentration of carbon dioxide will, directly and indirectly, impact biological diversity.[401] It will directly impact aquatic systems in many ways, including changes in water temperature and sea level.[402] The indirect impact of climate change on biological diversity includes differentiation in the degree and frequency of wildfires.[403] Other projected impacts of climate change on

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394 K. E. Kohfeld and S. P. Harrison, "How Well Can We Simulate Past Climates? Evaluating the Models Using Global Palaeoenvironmental Datasets" (2000) 19:1 Quaternary Science Reviews 321-346.
395 Convention on Biological Diversity Secretariat, Technical Series No.10, *supra* note 389, at 22.
396 J. B. C. Jackson and K. G. Johnson, "Life in the Last Few Millions Years" (2002) 26:4 Paleobiology 221-235
397 Convention on Biological Diversity Secretariat, Technical Series No.10, *supra* note 389 at 23.
398 Ibid.
399 Ibid.
400 Ibid.
401 Ibid., 36.
402 Ibid.
403 Ibid.

biological diversity by the Intergovernmental Panel on Climate Change (IPCC) include the significant loss of dominant species,[404] and the significant and irreversible changes to wetlands such as reefs, atolls, mangroves, tropical and boreal forests, and polar and alpine ecosystems due to their limited capacity to adapt to climate change.[405] Besides, the reefs and marine sanctuaries with legal protection are equally threatened by climate change.[406]

3.3.1.2 Marine Geoengineering Governance and Its Development under the CBD

Scientists and policymakers propose geoengineering as a stop-gap climate response,[407] yet they need help regulating this technology.[408] CBD does not directly address geoengineering; however, it contains relevant provisions capable of governing such activities.[409] For example, the duty to identify and monitor activities that are likely to adversely impact the conservation and the sustainable use of biodiversity significantly applies to marine geoengineering activities.[410] The previous chapter shows the impacts of these techniques on marine life and the marine environment. Also, the obligation to conduct an environmental impact assessment for projects that pose a risk to the conservation and sustainability of biodiversity is relevant in the context.[411]

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[404] Intergovernmental Panel on Climate Change (IPCC), *Climate Change and Biodiversity*, IPCC Technical Paper V., [Habiba Gitay, Avelino Suarez, Robert T. Watson, and David Jon Dokken (eds.)] (IPCC, 2002). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/32705/CCB.pdf?sequence=1&isAllowed=y. at section 6.2.2.

[405] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Impacts, Adaptation, and Vulnerability, Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, Cambridge University Press, 2001). Available at: https://www.ipcc.ch/site/assets/uploads/2018/03/WGII_TAR_full_report-2.pdf.

[406] James K. Reaser et al., "Coral Bleaching and Global Climate Change: Scientific Findings and Policy Recommendations" (2000) 14:5 Conservation Biology 1500-1511.

[407] Adam Lockyer & Jonathan Symons, "The National Security Implications of Solar Geoengineering: An Australian Perspective" (2019) 73:5 Australian Journal of International Affairs 485-503 at 485.

[408] Mark G. Lawrence et al., "Evaluating climate geoengineering proposals in the context of the Paris Agreement temperature goals" (2018) 9:1 Nature Communications 1-19 at 1.

[409] Melissa Eick, *supra* note 77 at 362.

[410] Convention on Biological Diversity, Art. 7.

[411] Convention on Biological Diversity, Art.14.

In the same vein, the expectation on States to institute measures to conserve biological diversity applies.[412]

The Conference of Parties (COP) has sought to govern geoengineering activities by adopting resolutions on marine geoengineering. In 2008, the Conference of Parties issued a moratorium on ocean fertilization activities within coastal waters. It requested the Contracting Parties and required non-parties to adopt a precautionary approach towards ocean fertilization activities by urging them to shelve it until there is an adequate scientific basis to justify such activities. However, it made an exception for the small-scale scientific research studies within coastal waters after conducting a prior assessment of the potential impact of the research on the marine environment.[413]

In response to the COP, the Secretariat of CBD prepared a synthesis report of the impacts of ocean fertilization on marine biodiversity.[414] It concluded that ocean fertilization altered the biological and chemical processes in the ocean, as there is an uncertainty of the role of the ocean in the global carbon cycle.[415] It recommended that there is a need to carry out an extensive and

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[412] Convention on Biological Diversity, Art. 8(a).

[413] Secretariat of the Convention on Biological Diversity, *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Ninth Meeting*, UNEP/CBD/COP/DEC/IX/16, (9 October 2008), at 7. Available at: https://www.cbd.int/doc/decisions/cop-09/cop-09-dec-16-en.pdf. [CBD Secretariat, DEC/IX/16]. The Intergovernmental Oceanographic Commission deemed the restriction of experiments to coastal waters as a new, arbitrary, and counterproductive limitation, since the ocean fertilization studies conducted before the issuance of the moratorium in an open ocean environment (a region often lacking micronutrients). The Commission noted a legitimate scientific reason to undertake large-scale studies on ocean fertilization. It argued that good scientific information from experiments is necessary to preserve biodiversity in marine systems. See, Intergovernmental Oceanographic Commission of UNESCO, Report on the IMO London Convention Scientific Group Meeting on Ocean Fertilization, IOC/INF-1247 (15 June 2008) at 4 and 5. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000160478?posInSet=1&queryId=N-EXPLORE-c03428aa-09ad-4607-af75-b26f2d865949.

[414] Secretariat of the Convention on Biological Diversity, *Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity*, CBD Technical Series No. 45, Montreal, 2009. Available at: https://www.cbd.int/doc/publications/cbd-ts-45-en.pdf. [CBD Secretariat, Technical Series No. 45].

[415] Ibid., 46 and 50.

targeted scientific experiment which will determine the degree of carbon sequestration, as well as interpret field data of the side effects and impacts of large-scale ocean fertilization.[416]

In 2010, the COP to CBD adopted decision X/33 to govern geoengineering.[417] The resolution called on Contracting Parties to take into consideration the impacts of mitigation activities that could adversely affect biological diversity and the provision of ecosystem services.[418] It stipulated that in accordance with article 14 of CBD and the precautionary principle, and 'in the absence of science-based, global, transparent, and effective control and regulatory mechanisms' all geoengineering activities that may affect biodiversity are prohibited from being carried out.[419] Geoengineering activities could only be undertaken if there is an adequate scientific basis, adequate risks assessment to the environment and biodiversity, and the impact of the activity on the social, economic, and cultural aspects of the environment.[420] Regarding ocean fertilization, the COP indicated that it must be addressed in line with decision IX/16 adopted under the London Convention/London Protocol.[421] Furthermore, the COP called on the SBSTTA to conduct a study on the possible impacts of the technique on biodiversity and other associated matters.[422]

In response to the request of the COP, the SBSTTA prepared a report to examine the potential impacts of geoengineering on biodiversity.[423] The report discovered that ocean acidification resulted in a shift in geographical distribution towards higher latitudes and higher elevations, phenological changes to the seasonal timing of life-cycle events, disruption of biotic

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[416] Ibid., 50.
[417] CBD Secretariat, Decision X/33, supra note 39.
[418] Ibid., 4.
[419] Ibid., 5.
[420] Ibid.
[421] Ibid.
[422] Ibid.
[423] CBD Secretariat, Technical Series No. 66, *supra* note 183.

interactions and an alteration in photosynthesis rates and primary productivity in the ocean.[424] Some of the socio-economic impacts of ocean acidification include a decrease in the availability of freshwater by 2050 in Central, South, East, and South-East Asia.[425] Regarding marine cloud brightening techniques using microbubbles, the report notes that there would be significant biodiversity and biogeochemical implications including the decrease in light penetration and temperature changes on phytoplankton, among others.[426] The report outlined potential impacts of several geoengineering techniques on biodiversity.

In response to decision X/33, the Executive Secretary to SBSTTA in 2012 circulated reports at the sixteenth meeting of SBSTTA. The first circular broadly examined the regulatory regime that could apply to geoengineering.[427] The circular identifies 'gaps' present in the existing legal framework.[428] Among others, it notes that the existing legal framework has not kept up with the evolution of geoengineering technologies[429] and adds that the lack of a regulatory mechanism for solar radiation mechanisms such as maritime cloud albedo enhancement is problematic.[430] Furthermore, the report acknowledged its shortcoming by indicating that it was prepared prior to geoengineering becoming a hot topic. Therefore, it does not contain references to geoengineering approaches.[431]

The second report prepared by SBSTTA examined the impact of geoengineering on biological diversity.[432] It indicates that a gradual increase in the atmospheric concentration of

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[424] Ibid., 36.
[425] Ibid., 43
[426] Ibid., 49.
[427] Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/29, *supra* note 368.
[428] Ibid.
[429] Ibid., 6.
[430] Ibid.
[431] Ibid., 7.
[432] Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), Impacts of Climate-Related Geoengineering on Biological Diversity, UNEP/CBD/SBSTTA/16/INF/28, (5 April 2012). Available at:

greenhouse gases could result in precipitation, ice-sheet dynamics, sea-level rise, ocean acidification, and the frequency and degree of extreme events.[433] The observed impacts and adaptations arising from climate change and geoengineering activities include a shift in geographical distribution towards higher latitudes and for higher elevations,[434] changes in the timing of life-cycle events tied to seasons,[435] alteration in photosynthesis rates and primary production in response to ocean fertilization activities. It observes that there is a degree of uncertainty associated with the large-scale deployment of geoengineering on marine ecosystems due to the complex interactions between physical, chemical, and biological processes.[436]

Another report presented by SBSTTA studied the impacts of geoengineering on biodiversity through the lens of indigenous and local communities and stakeholders.[437] The indigenous and local communities are among the most vulnerable populations to climate change.[438] The report outlined the lack of attention and consideration of the contributions of indigenous peoples and local communities to resolving issues of climate change.[439] It also notes that little is known about geoengineering among the indigenous people due to the use of technical language in the reports presented to the indigenous people.[440] Based on article 29 of the

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https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-28-en.pdf. [Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/28].

433 Ibid., 25.

434 Ibid.

435 SBSTTA, UNEP/CBD/SBSTTA/16/INF/28, *supra* note 426 at 31.

436 Ibid., 53.

437 Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), Impacts of Climate-Related Geoengineering on Biodiversity: Views and Experiences of Indigenous and Local Communities and Stakeholders UNEP/CBD/SBSTTA/16/INF/30 (17 April 2012). Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-30-en.pdf. [Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/30].

438 Ibid., 7.

439 Ibid., 6.

440 Ibid., 7; In some instances, the indigenous and local communities regarded geoengineering as a 'false solution' to climate change that adversely impacts them. See Indigenous Peoples' Global Summit on Climate Change, The Anchorage Declaration (24 April 2009). Available at: https://unfccc.int/resource/docs/2009/smsn/ngo/168.pdf at para. 6. Nevertheless, the report indicates that some indigenous communities' welcome geoengineering to understand better the complexities of the Earth's ecosystem, including the benefits and harms of deploying the

United Nations Declaration on the Rights of Indigenous Peoples, the international community ought to uphold the collective rights of these groups to their lands, territories, and resources, as well as the continuous use and enjoyment of their unique relationship to their lands and waters.[441] Thus, all geoengineering decisions must consider the rights of indigenous peoples and local communities.[442]

Furthermore, at the sixteenth meeting, the SBSTTA published a report which examined the technical and regulatory matters on geoengineering according to CBD.[443] This report outlined the impacts of geoengineering on biological diversity. It noted that biodiversity, ecosystems, and their services are essential to the well-being of humans; thus, it is necessary to prevent the loss of biodiversity.[444] The report noted the exponential increase in atmospheric concentration of carbon dioxide and the impacts it may have for precipitation, soil moisture, ice-sheet dynamics, sea-level rise, ocean acidification, among others.[445] The report further examined the potential impacts of several marine geoengineering techniques on the ocean environment.[446] It also looks at the socio-economic, cultural, and ethical consideration of geoengineering on the larger society. In this sense, it notes that geoengineering raises issues of global justice, the unequal spatial

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technology. See Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/30, *supra* note 437 at 8.

441 United Nations Declaration on the Rights of Indigenous Peoples, GA Res 61/295, UNGAOR, 61st Sess, Supp No 53, UN Doc A/RES/61/295, 46 ILM 1013 (2007), Art. 29.

442 Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/30, *supra* note 437 at 7.

443 Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), Technical and Regulatory Matters on Geoengineering in Relation to the Convention on Biological Diversity, UNEP/CBD/SBSTTA/16/10, (12 March 2012). Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/official/sbstta-16-10-en.pdf. [Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/10].

444 Ibid., 5.

445 Ibid., 7.

446 For instance, the report notes that ocean fertilization could increase biological primary production resulting in changes in phytoplankton community structure and species diversity, thereby having some implications for the food web. It also identifies the negative impacts of ocean terrestrial biomass storage on biodiversity.

distribution of impacts and benefits, and intergeneration equity.[447] Additionally, it perceives geoengineering as a 'moral hazard,' which hinders other mitigation efforts.[448] The report broadly examined the potential regulatory framework governing geoengineering, and in the process, it highlights the gaps in the framework.[449] According to the report, the lack of a regulatory mechanism for solar radiation methods such as marine cloud albedo enhancement, the inability of the framework to match up with the scale and scope of geoengineering, as well as the lack of clarity of the scope and application of certain general principles including the duty to avoid transboundary harm and the need to undertake environmental impact assessment (EIA).[450]

Additionally, at its sixteenth meeting, the SBSTTA made recommendations to the COP to adopt at its eleventh meeting.[451] It emphasized the need to address anthropogenic climate change swiftly and urgently.[452] It notes the findings in earlier reports of SBSTTA particularly the finding that there is no single geoengineering approach that is sufficiently effective, safe, and cheap to deploy.[453] The report recognizes the role of IPCC in providing a scientific and technical report of geoengineering and its impacts, and called on the SBSTTA to review the Synthesis Report of the IPCC when it becomes available and report on its implications for the CBD to the COP. [454] The report identifies the role and inadequacy of the rules of customary international law and the general principles of international law in governing the technology.[455] Furthermore, it requested the Executive Secretary to SBSTTA to collaborate with the relevant organizations to study the

[447] Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/10, *supra* note 443 at 11.
[448] Ibid., 12.
[449] Ibid., 17.
[450] Ibid., 16 to 18.
[451] Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/10, *supra* note 443.
[452] Ibid., 1.
[453] Ibid., 2.
[454] Ibid., 2 and 3.
[455] Ibid.

view of indigenous and local communities on the potential impacts of the technology on biodiversity and the social, economic, and cultural impacts on these communities.[456]

In 2012, the COP to CBD adopted a decision on climate-related geoengineering, taking into consideration the recommendations made by SBSTTA.[457] The decision emphasized the need to address climate change by reducing anthropogenic emissions by sources and by enhancing sinks of greenhouse gases. The decision reaffirmed the precautionary approach and acknowledged the resolutions adopted by the Contracting Parties to the London Convention and London Protocol in respect of geoengineering.[458] The decision noted the relevance of the application of customary international law rules as well as general principles of law such as the precautionary approach and the obligation to conduct EIA to geoengineering governance.[459] However, it added that these rules and principles would not constitute a complete basis for global regulation.[460] Essentially, the decision took into consideration the earlier decision by the COP and Contracting Parties to the London Convention/London Protocol.[461] It invited the Contracting Parties to CBD to enhance the knowledge and understanding of the impacts of geoengineering on biodiversity and further report on the measures taken to address them, drawing upon all relevant scientific reports such as the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.[462]

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456 Ibid., 3.
457 Secretariat of the Convention on Biological Diversity, *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Eleventh Meeting*, UNEP/CBD/COP/DEC/XI/20, (5 December 2012). Available at: https://www.cbd.int/doc/decisions/cop-11/cop-11-dec-20-en.pdf. [CBD, UNEP/COP/DEC/XI/20]
458 Ibid., 2.
459 Ibid.
460 Ibid.
461 Ibid., 1-3.
462 Ibid., 2.

Following the request by the COP, the SBTTA presented a report updating the potential impacts of geoengineering on biodiversity.[463] The report reviewed several scientific reports[464] and presented an updated report on the potential impacts of several geoengineering techniques, including Bioenergy with Carbon Capture and Storage (BECCS), Direct Air Capture, Marine Cloud Brightening, Ocean Fertilization, among others.[465] For instance, the report notes that regarding ocean fertilization, there is likely to be an increased mid-water and benthic decomposition and deoxygenation.[466] There is also the risk of an increase in harmful algal blooms and changes in water mixing in the case of ocean upwelling.[467]

3.3.2 Governance under the London Convention and London Protocol

There has been significant development in regulating marine geoengineering under this regime. This Part highlights the contributions of the London Convention and London Protocol in regulating marine geoengineering activities. This part will trace the history of marine geoengineering governance under this regime and discuss the developments made to ensure the regulation of these activities. Finally, the frailties of these developments, particularly the geoengineering amendment made to the London Protocol will be highlighted.

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[463] Secretariat of the Convention on Biological Diversity, *Update on climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework*, CBD Technical Series No. 84, Montreal, 2016, p.12. Available at: https://coherent-commons.s3.amazonaws.com/artifacts/file/file/db46d9ba-5423-4a90-a9c8-2043f1f444f3.pdf?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIA23B6R4NTCRHS5NZ3%2F20230518%2Fus-east-2%2Fs3%2Faws4_request&X-Amz-Date=20230518T170010Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=9de6b4e25330213ec41733f583c4c648039e90cb0905b58bbacbd89d5513c857. [CBD Secretariat, Technical Series No. 84].
[464] For example, the Report reviewed the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, the United States of America National Academy of Sciences report, and the UNEP Emissions Gap Report 2014.
[465] CBD Secretariat, Technical Series No. 84, *supra* note 463.
[466] Ibid., 98.
[467] Ibid.

3.3.2.1 The Regulation of Geoengineering Activities by the Provisions of the London Convention and London Protocol

The London Convention and London Protocol obligate all Contracting Parties to avoid marine pollution by dumping. According to this regime, all Contracting Parties must take adequate measures according to their capabilities to prevent pollution of the marine environment by dumping. According to this regime, all Contracting Parties are required to take effective measures according to their capabilities to prevent pollution of the marine environment by dumping.[468] Dumping is defined by the London Convention as the 'deliberate disposal at sea of wastes or other matter.'[469] It also includes the 'deliberate disposal of redundant of vessels, aircraft, platforms or other man-made structures at sea.'[470] The London Convention embodies the global standards referred to in Article 210 of UNCLOS.[471] Article III(a)(i) of the London Convention does not cover the subsoil, and this was vigorously debated between the 1980s and early 1990s within the context of radioactive waste disposal beneath the seabed.[472] However, in 1993 the Contracting Parties adopted Resolution LC. 51(16) which suspended any disposal of

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[468] London Convention, Art. II; London Protocol, Art 2. Also, article 7 of the London Protocol imposes an obligation on each Contracting Party to act at their discretion and either apply the provisions of the Protocol or adopt other effective permitting and regulatory measures to control dumping. The Contracting Parties must provide the International Maritime Organization with information on legislation and institutional mechanisms for the implementation, compliance, and enforcement in internal waters. The definition of "dumping" under the London Protocol does not cover using pipes fitted from land-based activities into the sea. Thus, article 7 of the London Protocol does not apply to marine geoengineering techniques such as ocean alkalinization, which deliberately uses pipes to dispose of substances into the sea. See London Protocol, Art. 1(1) and 7.

[469] London Convention, Art. III(a)(i); London Protocol, Art. 1(1).

[470] London Convention, Art. III(a)(ii); London Protocol, Art. 1(2).

[471] Karen N. Scott, "The Day After Tomorrow", *supra* note 364 at 74.

[472] Clifton E. Curtis, "Legality of Seabed Disposal of High-Level Radioactive Wastes Under the London Dumping Convention" (1985) 14:4 Ocean Development and International Law 383-415; Marianne Mackintosh, "The Development of International Law in Relation to the Dumping and Disposal of Radioactive Waste at Sea" (2003) 14 Journal of International Maritime Law 354; V. S. Mani, "Ocean Dumping of Radioactive Wastes: Law and Politics" (1984) 24:2 Indian Journal of International Law 224-244; Christopher Meisenkothen, "Subseabed Disposal of Nuclear Waste: An International Policy Perspective" (1999) 14:2 Connecticut Journal of international Law 631; James Waczewski, "Legal, Political and Scientific Response to Ocean Dumping and Sub-seabed Disposal of Nuclear Waste" (1997) 7 Journal of transactional Law and Policy 97-118; Hubertus Welsch, "The London Dumping Convention and Sub-Seabed Disposal of Radioactive Waste" (1985) 38 German Yearbook of International Law 322; ibid, Karen N. Scott, "The Day After Tomorrow", supra note 364 at 76.

radioactive waste into sub-seabed but declined to affirm that a disposal of this nature constituted dumping within the meaning of the London Convention.[473]

The London Protocol was agreed upon to modernize and replace the London Convention.[474] The London Protocol has been ratified or acceded to by 53 States.[475] This brings the total number of Contracting Parties to the London Convention and London Protocol to 100.[476] Unlike the Convention, the London Protocol defines disposal at sea to include the seabed and subsoil,[477] and extends the definition of dumping to include the 'storage of waste or other matter in the seabed and the subsoil'.[478]

Furthermore, the regime prohibits the placement of matter that is contrary to the object of the treaties.[479] The precise meaning of 'placement of matter' remains contested.[480] However, the sequestration of carbon in the ocean is contrary to the aims of the London Convention and London Protocol.[481] To avoid any uncertainty, the Resolutions adopted by the Contracting Parties to the London Protocol on marine geoengineering extends the scope of the dumping regime to cover marine geoengineering activities.[482]

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[473] Amendment to the Annexes to the Convention on the Prevention of Marine Pollution buy Dumping of Wastes and Other Matter, 1972, Concerning Disposal at Sea of Radioactive Wastes and other Radioactive Matter, IMO Res. LC.51/16 (1993).
[474] International Maritime Organization (IMO), "The London Convention and Protocol". Available at: https://www.imo.org/en/KnowledgeCentre/ConferencesMeetings/Pages/London-Convention-Protocol.aspx; Robin Warner, *supra* note 303 at 433.
[475] London Protocol, Art. 25(1); International Maritime Organization, Report of the Forty-Fourth Consultative Meeting and the Seventeenth Meeting of Contracting Parties, Resolution LC 44/17 (20 October 2022), para. 2.2. [International Maritime Organization, Resolution LC 44/17].
[476] Ibid., para. 2.2.
[477] London Protocol, Art. 1(7).
[478] London Protocol, Art. 1(4)(3).
[479] London Convention, Art. III(1)(b); London Protocol, Art. 1(4)(2)(2).
[480] Alan Boyle & Catherine Redgwell, *International Law and the Environment* (Oxford: Oxford University Press, 2021).
[481] Karen N. Scott, "The Day After Tomorrow", *supra* note 364 at 77.
[482] Robin Warner, *supra* note 303 at 233; Birnie, Boyle & Redgwell, *supra* note 155 at 483.

The regulation of carbon dioxide sequestration in the ocean by the London Protocol is straightforward. The Protocol adopts a reverse listing technique, thus prohibiting the dumping of all wastes into the ocean except items listed in Annex I.[483] This implies that all marine geoengineering activities other than those that employ the category of wastes permitted for dumping by the Protocol may be prohibited.[484]

3.3.2.2 Resolutions by Contracting Parties on Geoengineering

The first ever deliberation by the Parties to the London Convention/Protocol on the sequestration of carbon in the ocean was in the 1990s.[485] At its Twenty-First Consultative Meeting, the issue of whether the storage of carbon in the ocean was consistent with the dumping regime was first raised.[486] However, it was until 2004, that the parties called for the inclusion of the issue in the work program spearheaded by the United Kingdom (UK).[487]

In 2006, the Conference of Parties commissioned the Scientific Group's Intersessional Technical Working Group to prepare a report on the risk assessment and management framework for carbon dioxide sequestration in seabed and geological structures.[488] This entity was tasked to develop a framework which is compatible with Annex 2 to the London Protocol. The framework is to provide guidance to Contracting Parties[489] on the categorization of the risks

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[483] London Protocol, Art. 4(1)(1).
[484] Grant Wilson, "Murky Waters: Ambiguous International Law for Ocean Fertilization and other Geoengineering" (2014) 49:1-3 Texas International Law Journal 507 at 534.
[485] Karen N. Scott, "The Day After Tomorrow", supra note 364 at 78.
[486] Ibid.
[487] Ibid.
[488] Scientific Group's Intersessional Technical Working Group, Risk Assessment and Management Framework for CO2 Sequestration in Sub-Seabed Geological Structures, LC/SG-CO2 1/7, annex 3, available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi_vMnU_P_-AhWDFFkFHZLlBnAQFnoECBkQAQ&url=https%3A%2F%2Fwwwcdn.imo.org%2Flocalresources%2Fen%2FOurWork%2FEnvironment%2FDocuments%2FCO2SEQUESTRATIONRAMF2006.doc&usg=AOvVaw1bFH29h2QYxNUZsb3QzOzx.
[489] Ibid., para. 0.1.

to the marine environment from carbon dioxide sequestration in the seabed and geological structures, as well as, gather relevant data to address uncertainties and residual risks associated with the enterprise.[490] At the joint session of the Twenty-Eighth Consultative Meeting of the Contracting Parties under the London Convention and the 1st Meeting of the Contracting Parties under the London Protocol, this framework was adopted.[491]

In 2007, the International Maritime Organization (IMO) raised concerns about ocean fertilization of the ocean.[492] It issued a 'Statement of Concern' regarding large-scale iron fertilization of the ocean and took into consideration the concerns raised by the Scientific Groups of the London Convention/London Protocol, as well as the IPCC regarding ocean fertilization.[493] Based on the request of the Scientific Groups to the Contracting Parties to consider issues of large-scale ocean fertilization activities, the Contracting Parties invited all State Parties to the Convention and Protocol to take into consideration the 'Statement of Concern' when assessing ocean fertilization applications and provide further information to the Secretariat and the Scientific Group when it becomes available.[494]

In 2008, the IMO put to bed the debate as to whether ocean fertilization fell within the scope of the dumping regime of the London Convention and London Protocol.[495] The

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490 Ibid.
491 International Maritime organization, The First Meeting of Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter 1972, Resolution LP.1(1) (2 November 2006), available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LP.1(1).pdf.
492 International Maritime Organization (IMO), Convention on the Prevention of marine Pollution by Dumping of Wastes and other Matter, 1972 and its 1996 Protocol, LC-LP.1/Circ. 14, 13 July 2007. Available at: https://www.whoi.edu/cms/files/London_Convention_statement_24743_29324.pdf.
493 Ibid., 1.
494 Ibid., 2.
495 International Maritime Organization (IMO), The Thirtieth Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol, Resolution LC-LP.1 (31 October 2008) at 1. Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LC-LP.1%20(2008).pdf. [International Maritime Organization (IMO) Resolution LC-LP.1(1)].

Contracting Parties agreed that to be able to allow legitimate scientific research of ocean fertilization, the activity must be regarded as the placement matter in the ocean beyond the scope of mere disposal as stipulated under article III.1(b)(ii) of the London Convention and article 1.4.2.2 of the London Protocol.[496] Furthermore, the Contracting Parties agreed that all research proposals must be assessed using an assessment framework which will be developed by the Scientific Group under the London Convention and Protocol.[497] Additionally, it called for the prohibition of all ocean fertilization activities except legitimate scientific research experiments.[498] Furthermore, the resolution indicated that until specific guidance is available, the Contracting Parties must use utmost caution and the best available guidance to evaluate research proposals to ensure the protection of the environment.[499]

In 2009, the Contracting Parties adopted the amendment to article 6 of the London Protocol, which allowed the transboundary export of carbon dioxide for purposes of disposal in the seabed.[500] The decision welcomed resolution LP.1(1), which amended the London Protocol to permit the sequestration of carbon dioxide streams under the seabed.[501] The 2009 Resolution amended article 6 of the London Protocol to permit 'the export of carbon dioxide streams for disposal in accordance with annex 1… provided that an agreement or arrangement has been entered into by the countries concerned'.[502] This amendment is yet to enter into force since the

[496] Ibid., 2.
[497] Ibid., 2.
[498] Ibid.
[499] Ibid.
[500] International Maritime Organization (IMO), The Fourth Meeting of Contracting Parties to the 1996 Protocol of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other matter 1972, Resolution LP.3(4) (30 October 2009). Available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Resolution%20LP-3(4).doc. [International Maritime Organization (IMO)][International Maritime Organization (IMO) Resolution LP.3(4)].
[501] International Maritime Organization (IMO) Resolution LC-LP.1(1), *supra* note 495 at 1.
[502] International Maritime Organization (IMO) Resolution LP.3(4), *supra* note 500 at 3.

amendment required a change to the text of 1996 of the London Protocol, as opposed to the annexes in accordance with article 21.[503]

In 2010, the Contracting Parties adopted the Assessment Framework for Scientific Research Involving Ocean Fertilization (Assessment Framework) to be used in determining ocean fertilization proposals which constitutes legitimate scientific research that is not contrary to the aims of the London Protocol and London Convention.[504] The Contracting Parties decided that all legitimate scientific research proposals must be assessed using the Assessment Framework.[505] It urged all Contracting Parties to apply the precautionary approach when using the Assessment Framework to assess proposals of ocean fertilization research.[506] The Parties reaffirmed that ocean fertilization activities are not exempted from the application of the dumping regimes of the London Convention and London Protocol.[507] Furthermore, the Resolution reaffirmed that the Convention and Protocol must continue to provide a global, transparent, and effective control and regulatory mechanism for geoengineering that falls within the scope of the London Convention and London Protocol.[508] Also, the resolution urged the Contracting Parties to review the Assessment Framework at appropriate intervals as time goes on.[509]

In November 2011, a joint meeting of the Contracting Parties to the Convention and Protocol reviewed several reports from the Intersessional Working Group on Ocean Fertilization

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[503] London Protocol, Art. 21; Alan Boyle & Catherine Redgwell, *supra* note 474 at 482.
[504] International Maritime Organization (IMO), The Thirty-Second Consultative Meeting of the Contracting Parties to the London Convention and the Fifth Meeting of the Contracting Parties to the London Protocol*,* Resolution LC-LP.2 (2012) (14 October 2010). Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LC-LP.2(2010).pdf.
[505] Ibid., 1.
[506] Ibid., 1.
[507] Ibid., 2.
[508] Ibid., 1.
[509] Ibid., 2.

and the Correspondence Group on Ocean Fertilization.[510] The Correspondence Group on Ocean Fertilization presented some amendment proposals to the London Protocol. It proposed for (a) a draft amendment to the London Protocol must be carried out to allow ocean fertilization as placement using a single article and annex;[511] (b) a draft amendment to the London Protocol to permit ocean fertilization as placement using multiple annexes;[512] (c) the implementation of the Assessment Framework adopted in Resolution LC-LP.2 and taking stock of the experience in the implementation of the Framework;[513] (d) further development of an interpretative resolution.[514] The meeting did not pass any final resolution regarding the work of the Correspondence Group on Ocean Fertilization.[515] The Contracting Parties commissioned the Scientific Groups to investigate the feasibility of developing a web-based repository of reference for the Assessment Framework that will be accessible by all Parties in collaboration with other forums such as the CBD.[516]

In 2012, the feasibility report on the development of a repository of reference for the Assessment Framework was presented in Jeju Korea.[517] The outcome of the deliberation among the Scientific Group did not yield any consensus as to the feasibility, utility, and content of a generic Assessment Framework.[518] Thus, the task was forwarded to the London Protocol's 4th Intersessional Working Group on Ocean Fertilization to consider at its meeting in Bonn, Germany in July 2012.[519] At this meeting, Australia proposed for an amendment to the London

[510] International Maritime Organization (IMO) "Ocean Fertilization under the LC/LP", available at: https://www.imo.org/en/OurWork/Environment/Pages/OceanFertilization-default.aspx.
[511] Ibid.
[512] Ibid.
[513] Ibid.
[514] Ibid.
[515] Ibid.
[516] Ibid.
[517] Ibid.
[518] Ibid.
[519] Ibid.

Protocol which will regulate the placement of matter for marine geoengineering.[520] The Contracting Parties met in London in November 2012 to review the report of the Intersessional Working Group prior to the meeting and a new task to develop a global, transparent and effective mechanism for ocean and other activities that fall within the scope of the London Convention and Protocol.[521] Based on the reports of the Intersessional Working Group and the discussion at plenary, the Contracting Parties established an Intersessional Corresponding Group to further develop a text which will set out a procedure for listing new activities in the proposed Annex 4 titled 'Regulated Marine Geoengineering Activities'.

Pursuant to Resolution LP.4(8), the Contracting Parties adopted the amendment to the London Protocol to regulate the placement of matter of ocean fertilization and other marine geoengineering activities.[522] The Resolution reemphasized the application of the London Convention and London Protocol to ocean fertilization activities.[523] It emphasized that marine geoengineering activities must not be considered as substitutes for climate change mitigation measures.[524] In accordance with article 21 of the London Protocol, the resolution amended the Protocol by; (a) reaffirming that resolutions LC-LP.1(2008) and LC-LP.2(2010) remain in force pending the entry into force of the amendments to the London Protocol;[525] (b) confirming that the Assessment Framework adopted by the Contracting parties in resolution LC-LP.2(2010) is the relevant Assessment Framework referred to in Annex 4 and further that it must continue to be

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[520] Ibid. Australia's proposal called for a proposed new article and two new annexes. The new article was to regulate marine geoengineering activities, and the two new annexes were to list the marine geoengineering activities to be regulated and a Generic Assessment Framework for marine geoengineering activities.
[521] Ibid.
[522] International Maritime Organization (IMO), *The Eight Meeting of Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter 1972,* Resolution LP.4(8), Annex 4 (18 October 2013). Available at: https://www.gc.noaa.gov/documents/resolution_lp_48.pdf. [International Maritime Organization (IMO), Resolution LO.4(8) Annex 4].
[523] Ibid., 1.
[524] Ibid., 2.
[525] Ibid.

used (with utmost caution) to determine whether a proposed ocean fertilization activity constitutes legitimate scientific research that is not contrary to the aims of the Protocol;[526] (c) reaffirming that new scientific information and knowledge on marine geoengineering activities should continuously be reviewed by the Parties;[527] (d) deciding that the Contracting Parties must work continue to develop guidance for listing additional marine geoengineering activities in annex 4;[528] and (e) deciding that the Contracting Parties must develop the arrangement for seeking independent advice referred to in paragraph 12 of annex 5.[529]

In recent times, the Contracting Parties to the London Protocol have adopted additional resolutions on marine geoengineering. In 2019, the Contracting Parties to the London Protocol adopted resolution LP.5(14) which allowed provisional application of an amendment to Article 6 of the London Protocol which allows sub seabed geological formation for carbon dioxide sequestration projects to be shared across national boundaries. [530] In 2022, the governing body of the London Convention and London Protocol reminded the Contracting Parties to the Convention and Protocol of the importance of the 2013 amendment to the London Protocol to the governance of marine geoengineering.[531] It urged its members to ratify the amendment to enable the Contracting Parties to address climate change, while regulating marine geoengineering on a precautionary basis.[532]

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[526] Ibid.
[527] Ibid.
[528] Ibid.
[529] Ibid.
[530] International Maritime Organization, Report of the Fourteenth Meeting of the Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution, Resolution LP.5(14) (11 October 2019). Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LP.5(14).pdf. [International Maritime Organization, Resolution LP.5(14)].
[531] International Maritime Organization, Resolution LC 44/17.
[532] Ibid., 5.5.

The Contracting Parties to the London Protocol prioritized four marine geoengineering techniques as those to be listed in Annex 4 (in addition to ocean fertilization) of the London Protocol.[533] These techniques are ocean alkalinization, macroalgae cultivation and other biomass for sequestration including artificial upwelling, increasing ocean reflectivity, and marine cloud brightening techniques.[534] The Contracting Parties were urged to commission legal experts to consider: (i) whether these techniques were within the scope of the London Convention and London Protocol; (ii) how existing assessment frameworks applied and if they were adequate for assessing these techniques; (iii) if needed, adjust existing frameworks or develop new frameworks to address gaps; and (iv) which of the techniques were suitable for listing in Annex 4 of the London Protocol.[535]

At the meeting of Contracting Parties in 2022, a Working Group on Marine Geoengineering was established to perform tasks related to marine geoengineering governance. The Working Group was expected to develop proposals for actions to promote awareness of the work of the London Protocol and London Convention on marine geoengineering, draft any proposed additional actions for the Contracting Parties, Secretariat, and Scientific Group, establish the parameters of the legal analysis on the scope of application of the London Convention and London Protocol on the four marine geoengineering techniques, and present a report.[536] Subsequently, the Working Group presented a Statement on marine geoengineering which was approved by the governing body.[537] Furthermore, it proposed (and was approved by the governing body) the establishment of a Legal Intersessional Correspondence Group (LICG)

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[533] Ibid., para. 5.8. These four techniques were prioritized because of the advancements made in those fields and the potential economic interest they may generate. See Ibid., para. 5.9.
[534] Ibid.
[535] Ibid., para 5.10.
[536] Ibid., para. 5.14.
[537] Ibid., para. 5.17.

on Marine Geoengineering, under the lead of Canada and Germany, to address the legal issues surrounding marine geoengineering.[538]

In 2023, at the meeting of Contracting Parties to the London Convention and Protocol, it was observed that since the inception of the London Protocol, four amendments have been adopted, and three of them apply to marine geoengineering[539]. These amendments are: (i) amendment on the inclusion of carbon dioxide sequestration in sub-seabed geological formation in annex I of the London Protocol, (ii) amendment on the export of carbon dioxide streams for disposal in accordance with annex 1, resolution LP.3(4) from 2009; and (iii) amendment on the regulation of the placement of matter for ocean fertilization and other marine geoengineering activities. It is instructive note that the latter two are yet to enter into force.[540]

Subsequently, in 2023, a progress report on marine geoengineering governance from the LICG on Marine Geoengineering was submitted to the Contracting Parties to the London Convention and London Protocol.[541] The report was to consider actions on the implementation of the 2013 amendment to the London Protocol. In this context, two issues were to be resolved: whether a mechanism for provisional application of the 2013 amendment to the London Protocol (before its entry into force) is needed for implementation, or whether domestic implementation could proceed without a mechanism for provisional application); and consider the drafting of a statement to the effect that no actions to undermine the object and purpose of the amendment must be taken by the Parties to the London Convention and Protocol.[542]

[538] Ibid.
[539] International Maritime Organization, Report of the Forty-Fifth Consultative Meeting of Contracting Parties to the London Convention & Eight Meeting of Contracting Parties to the London Protocol, Resolution LC 45/2 (27 June 2023). International Maritime Organization, Resolution LC 45/2].
[540] Ibid.
[541] International Maritime Organization, Report of the Forty-Fifth Consultative Meeting of Contracting Parties to the London Convention & Eight Meeting of Contracting Parties to the London Protocol, Resolution LC 45/25/1 (30 June 2023) [International Maritime Organization, Resolution LC 45/25/1].
[542] Ibid., para. 1.

The legal analysis in the 2023 progress report of the LICG is based on four marine geoengineering techniques – macroalgae cultivation, alkalinization, albedo enhancement, and marine cloud brightening.[543] The legal analysis in the report considered four things, that is, whether (i) the scenarios of the four marine geoengineering techniques were within the scope of the London Protocol; (ii) whether the London Protocol can regulate any activity that is not dumping or placement; (iii) whether the London Protocol can regulate these activities especially when there is no deposit of material at sea from a shift, aircraft, platform, or other structure; and (iv) whether there are limits for the 2013 amendment of the London Protocol for the regulation of marine geoengineering.[544]

The progress report presented by the LICG considered whether ocean alkalinization constitutes "ocean fertilization" and whether it fell within the scope of the amendment to the London Protocol. It indicated that ocean alkalinization process which involves adding alkaline matter to the ocean is within the scope of the amendments of the London Protocol.[545] However, the technique does not constitute "ocean fertilization" because there is no intention to stimulate primary productivity in the ocean.[546] Ocean alkalinization methods using electrochemistry fell within the scope of the amendments to the London Protocol.[547] However, the process did not constitute ocean fertilization.[548] Ocean alkalinization methods using reactors with discharge of a carbon dioxide equilibrated solution could be within the scope of the amendments to the London Protocol, but it does not constitute ocean fertilization.

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[543] Ibid., para. 1 and 2.
[544] Ibid., para. 1.
[545] Particularly Articles 6*bis* No.1, 1 No.4.2.2, 1 No.7, and 1No.5b*is*. See Ibid., Annex 1-2.
[546] Ibid., Annex 3.
[547] Ibid, Annex 4-5.
[548] Ibid., Annex 6.

The next marine geoengineering technique considered by the report is the storage of carbon dioxide by the cultivation of macroalgal. In this context, the LICG stated that all categories of macroalgal cultivation for marine geoengineering purposes fell within the scope of the amendment of the London Protocol.[549] Regarding whether it constitutes ocean fertilization, the experts note that macroalgal cultivation methods in the sea and for artificial upwelling methods constitutes ocean fertilization.[550] However, microalgae farming, macroalgae farming on land and macroalgae farming for terrestrial biomass sinking do not constitute ocean fertilization because it does involve stimulating primary productivity in the oceans.[551]

The report also considered surface albedo enhancement techniques. According to the LICG, each variant of surface albedo enhancement techniques fell within the scope of the amendment to the London Protocol.[552] However, it does not constitute ocean fertilization because there is not principal intention to stimulate primary productivity in the ocean,[553] and it is not included in conventional aquaculture, or mariculture, or the creation of artificial reefs.[554]

The LICG studied the marine cloud brightening process and argued that it arguable whether the technique fell within the scope of the amendments. The report notes that its arguable whether marine cloud brightening technique constitutes "placement of matter" within article 6*bis*.[555] Furthermore, this technique does not constitute ocean fertilization because the principal intention of the technique is not to stimulate primary productivity in the ocean.[556]

[549] Ibid., Annex 10-11.
[550] Ibid., Annex 12.
[551] Ibid.
[552] Ibid., Annex 13-15.
[553] Ibid., Annex 15.
[554] Ibid.
[555] Ibid., Annex 16-17.
[556] Ibid., Annex 18.

3.3.2.3 Amendment to the London Protocol on the Regulation of the Placement of Matter for Marine Geoengineering

Resolution LP.4(8) amended the London Protocol by amending Article 1 and inserting a new article and two other annexes to regulate marine geoengineering.[557] Article 5bis is inserted into article 1 to cater to the definition of marine geoengineering. According to Article 5bis, "marine geoengineering" refers to 'a deliberate intervention in the marine environment to manipulate natural resources, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, [long-lasting] or severe'.[558] According to Kerryn Brent, any activities that may be governed by resolution LP.4(8) and the amendments, must fall within the definition in article 5bis.[559] Also, the scope of the definition does not apply to non-deliberate activities that manipulate natural processes as a consequence such as the laying of submarine cables and the creation of artificial reefs.[560] Furthermore, the definition does not apply to activities that do not have "deleterious effects" on the marine environment, even though the threshold for measuring harm is very low.[561] That is, the potential risk of harm is sufficient to deem the activity as having "deleterious effects".[562]

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[557] International Maritime Organization (IMO), Resolution LO.4(8) Annex 4, *supra* note 522.
[558] London Protocol, Art. 5bis.
[559] Kerryn Brent, *Governance of Marine geoengineering* (Ontario, Canada: Centre for International Governance Innovation, 2019), at 46.
[560] Harold Ginzky & Robyn Frost, "Marine Geo-Engineering: Legally Binding Regulation under the London Protocol" (2014) 8:2 Carbon & Climate Law Review 82.
[561] Karen N. Scott, "Mind the Gap: Marine Geoengineering and the Law of the Sea" in Robert C Beckman et al., eds, High Seas Governance: Gaps and Challenges (Leiden: Brill Neijhoff, 2019) at 45. [Karen N. Scott, "Mind the Gap"].
[562] Kerryn Brent, *supra* note 559 at 45.

The amendment is not adequately comprehensive to cover marine geoengineering activities which do not constitute the "placement of matter" into the ocean.[563] Activities such as the extraction of seawater for purposes of SRM purposes and enhancing the reflectivity of the ocean would not fall within the scope of this regulation.[564] Likewise, activities that introduce energy into the ocean may equally fall outside the scope of the amendment, particularly article 6bis.[565] Activities such as ocean fertilization, all forms of carbon sequestration in the ocean, enhanced microalgae cultivation or kelp farming fall within the ambit of the amendment.[566] However, ocean upwelling and downwelling that transmit nutrients from one region of the ocean to another are beyond the scope of article 6bis.[567]

The annexures allow for the regulation of other marine geoengineering activities beyond ocean fertilization. The annexes allow for some degree of flexibility in the regulation of future marine geoengineering proposals.[568] Annex 4 prohibits ocean fertilization activities other than conventional aquaculture, mariculture, or the creation of artificial reefs.[569] It also offers the Contracting Parties an avenue to regulate other marine geoengineering proposals without having to amend the Protocol.[570] Any Party could add to the list of marine geoengineering activities under Annex 4, subject to the acceptance by two-thirds majority of the London Protocol.[571] Such amendments will be effective after 100 days of receiving the support of two-thirds of the Parties.[572]

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[563] Article 6bis of the London Protocol prohibits "… the placement of matter into the sea from vessels, aircraft, platforms or other manmade structures at sea for marine geoengineering activities listed in annex 4."; Ibid at 46.
[564] Harold Ginzky & Robyn Frost *supra* note 560 at 86.
[565] Ibid.
[566] Karen N. Scott, "Mind the Gap", *supra* note 561, at 459.
[567] Harold Ginzky & Robyn Frost *supra* note 560.
[568] Kerryn Brent, *supra* note 559 at 44.
[569] London Protocol, Art. 4bis.
[570] Kerryn Brent, *supra* note 559 at 44.
[571] London Protocol, Art. 22(2)-(4).
[572] Ibid.

The new amendment readily makes it convenient to regulate marine geoengineering actions under the London Protocol. Annex 4 attests to the convenience with which the Protocol could govern a new marine geoengineering activity.[573] Also, Annex 4 allows parties to either prohibit a marine geoengineering activity outrightly or create circumstances under which the activity may be allowed subject to an issue of a permit by a Contracting Party.[574]

The Generic Assessment Framework under Annex 5 urges parties to adopt a precautionary approach when determining marine geoengineering proposals.[575] According to Kerryn Brent et al, the Assessment Framework has two broad purposes, which the Contracting Parties could use to determine whether a marine geoengineering activity which is not contrary to the aim of the Protocol ought to take place.[576] The Framework possesses the flexibility to create customized assessment frameworks for specific marine geoengineering proposals, similar to how the framework was customized the Ocean Fertilization Assessment Framework to govern Ocean Iron Fertilization research.[577] Also, it allows States to determine whether to carry out a marine geoengineering activity listed in Annex 4.[578] Besides, the Assessment Framework is significantly informed by scientists, environmental policymakers, and international lawyers' advice.[579]

Notwithstanding the crucial framework presented by Resolution LP.4(8), Kerryn Brent et al. argue that the amendment does not govern research and development of geoengineering technologies.[580] Despite the role of the assessment framework in governing marine geoengineering activities, the lack of ratification on the parts of Member States limits the

[573] Chiara Armeni and Catherine Redgwell, *supra* note 54 at 26–27.
[574] International Maritime Organization (IMO), Resolution LP.4(8), *supra* note 516, Annex 5 para. 26.
[575] Karen N. Scott, "Mind the Gap", *supra* note 561 at 50.
[576] Kerryn Brent, *supra* note 559 at 45.
[577] Ibid.
[578] Ibid.
[579] Harold Ginzky & Robyn Frost *supra* note 560 at 94.
[580] Kerryn Brent, *supra* note 559 at 45.

effectiveness of Resolution LP.4(8).[581] The prospects of the amendment coming into force looks bleak, considering that only a handful of parties have accepted the amendment.[582] Thus, resolutions LC-LP.1(2008) and LC-LP.2(2010) remain in force pending the entry into force of the amendments to the London Protocol.[583]

3.4 Contributions of the United Nations Environment Assembly (UNEA)

UNEA contributes immensely to global environmental governance and has been referred to as the "world's parliament on the environment".[584] The United Nations General Assembly (UNGA) established the United Nations Environment Programme (UNEP) General Council – which later became UNEA - following the recommendation made at the 1972 Stockholm Conference.[585] The UNGA established UNEP as a permanent institution within the United Nations (UN) system for international environmental cooperation.

UNEA's core responsibility is to periodically review the status quo of global environment and outline the challenges in the process.[586] According to Franz Xaver Perez, the mandates of UNEA are three:[587] first is to review and identify emerging environmental issues with international significance; the second is to promote international cooperation, provide general

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[581] Ibid.
[582] David Langlet, "Using the Continental Shelf for Climate Change Mitigation: A Baltic Sea Perspective" in *Regulatory Gaps in Baltic Sea Governance* (Switzerland: Springer International Publishing, 2018) at 183. [David Langlet, "Using the Continental Shelf for Climate Change Mitigation: A Baltic Sea Perspective"]. Presently, on six parties have accepted the 2013 amendments. See International Maritime Organization, Resolution LC 44/17, para. 2.3.
[583] International Maritime Organization (IMO), Resolution LO.4(8) Annex 4, *supra* note 522 at 2.
[584] Lynn Wagner, "The United Nations Environment Assembly's Role as a Governance Architect" CE Think Tank Newswire (28 February 2022). Available on: https://www.proquest.com/docview/2634789297?pq-origsite=primo&parentSessionId=TBODHjVZa9DqWXk01rcVT0SXvKV2HLyViRYHm8J4K0Q%3D.
[585] Franz Xaver Perrez, "The Role of the United Nations Environment Assembly in Emerging Issues of International Law" (2020) 12:114 Sustainability 5680 at 5.
[586] Miranda Boettcher & Rakhyun E. Kim, "Arguments and Architectures: Discursive and Institutional Structures Shaping Global Climate Engineering Governance" (2022) 128 Environmental Science & Policy 121-131 at 126.
[587] Franz Xaver Perrez, *supra* note 585.

policy guidance, and coordinate the environmental activities within UN; and the third mandate is to stimulate environmental cooperation, action, and policy implementation.[588] The objective of UNEA is to strengthen UNEP's capacity to undertake its coordinating responsibilities and to empower it to lead in developing comprehensive strategies on environmental matters within the UN system.[589]

UNEA has played significant roles in addressing issues of environmental law in the past.[590] For instance, it conducted a global mercury assessment, established the Mercury Programme that documented best practices, established voluntary guidelines, and facilitated negotiations of the Minamata Convention[591] among others.[592] These contributions significantly contributed to the efforts used to address the risks posed by mercury.[593] In recent times, the UNEA facilitated the negotiation of a treaty to end plastic pollution.[594]

UNEA must live up to expectations in negotiating a marine geoengineering governance framework. In 2019, a draft resolution for consideration of an assessment of geoengineering was rejected.[595] In 2019, Switzerland presented a draft resolution on geoengineering governance for consideration at the 4th UNEA.[596] At the core of this draft resolution, Switzerland supported by other 11 other countries[597] were a request to Executive Director of UNEP to gather information

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[588] Ibid.
[589] Ibid., Franz Xaver Perrez; Miranda Boettcher & Rakhyun E. Kim, *supra* note 586.
[590] Ibid., 14.
[591] Minamata Convention on Mercury, 10 October 2013, 3202 UNTS 560 (entered into force 16 August 2017).
[592] Franz Xaver Perrez, *supra* note 585 at 13.
[593] Ibid.
[594] United Nations Environment Programme, "Historic Day in the Campaign to Beat Plastic Pollution: Nations Commit to Develop a Legally Binding Agreement", online: https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop.
[595] United Nation Environment Assembly, "Resolution for Consideration at the 4th United Nations Environment Assembly: Geoengineering and its Governance" submitted by Switzerland and supported by Burkina Faso, Federal States of Micronesia, Georgia, Liechtenstein, Mali, Mexico, Montenegro, Niger, Republic of Korea, and Senegal. Available at: https://geoengineering.environment.harvard.edu/files/sgrp/files/draft_unea_resolution.pdf.
[596] Franz Xaver Perrez, *supra* note 585.
[597] The eleven countries were Burkina Faso, Federal States of Micronesia, Georgia, Liechtenstein, Mali, Mexico, Montenegro, Niger, Republic of Korea, and Senega.

and a proposal to develop a governance framework for CDR and SRM techniques.[598] The proposal faced opposition from some countries including European Union (EU), Bolivia, US, and Saudi Arabia.[599] EU and Bolivia argued that the draft resolution will weaken the efforts taken by Contracting Parties under multilateral agreements such as CBD to regulate geoengineering.[600] The US and Saudi Arabia opposed the bill on the basis that it sought to pre-empt the Sixth Assessment Report of the IPCC which is due in 2021-2022.[601] Additionally, the US raised concerns about the attempt by the bill to clothe UNEA with the mandate to make governance recommendations.[602]

Following the opposition, Switzerland revised the bill to reflect and address the opposition raised against the bill. The revised bill requested the Executive Director of UNEP to assess the status of CDR and SRM techniques, establish an ad hoc Independent Expert Group to advise the Executive Director on the development of geoengineering, engage relevant UN entities, and submit the assessment at the fifth session of the UNEA.[603] Due to lack of consensus between States, Switzerland and its co-sponsors withdrew the revised bill.[604] Some have argued that the introduction of the phrase "precautionary principle" in the revised bill contributed to the lack of consensus, especially from the US.[605]

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598 Sikina Jinnah& Simon Nicholson, "The Hidden Politics of Climate Engineering" (2019) 12:11 Nature 876-879.
599 Franz Xaver Perrez, *supra* note 585 at 11 and 12.
600 Ibid.
601 Sikina Jinnah& Simon Nicholson, *supra* note 598 at 887.
602 Ibid.
603 United Nation Environment Assembly, "Resolution for Consideration at the 4th United Nations Environment Assembly: Geoengineering and its Governance", *supra* note 253.
604 Franz Xaver Perrez, *supra* note 585 at 13; Sikina Jinnah& Simon Nicholson, *supra* note 598 at 887.
604 Ibid.
605 Ibid.

CHAPTER FOUR: REGIONAL GOVERNANCE OF MARINE GEOENGINEERING: LESSONS FROM SELECTED REGIONAL SEAS PROGRAMME

Besides the global efforts to govern marine geoengineering activities, some attempts have been made at the regional level to govern marine geoengineering. This Chapter discusses the governance approaches instituted by three regions - the Baltic Seas, the Mediterranean Seas, and the North-East Atlantic Seas region – to govern marine geoengineering. These regional seas program fall within the UNEP Regional Seas Program umbrella and are either administered by UNEP[606] or are independent of UNEP.[607]

Each of these Regional Seas Programme adopts a diverse and unique approach in instituting a governance framework for geological carbon sequestration activities in the ocean. [608] Whereas most of the marine geoengineering activities is governed by the dumping regimes of these regional sea conventions, there are instances where other steps, such as an amendment to a regional sea convention, guidelines, or action plans, governs these activities.

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[606] United Nations Environment Programme, "Regional Seas Programme". Available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/regional-seas-programme. [UNEP Regional Seas Programme]. The regional seas programs administered by UNEP have a Regional Seas Convention and Action Plans administered by UNEP.

[607] Ibid. The independent regional seas program does not have a Regional Seas Convention and Action Plan established by UNEP; however, these programs cooperate with it and attend regular meetings.

[608] For the regional convention operating in the Baltic Sea Region, see the Convention on the Protection of the Marine Environment of the Baltic Sea Area 22 March 1974, 1507 UNTS 166 (entered into force on 3 May 1980). Available at: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-5&chapter=27&clang=_en. [Helsinki Convention]; in the North-East Atlantic Region, see Convention for the Protection of the Marine Environment of the North-East Atlantic, 22 September 1992, 2354 UNTS 67 (entered into force 25 March 1998). Available at: https://treaties.un.org/pages/showdetails.aspx?objid=0800000280069bb5. [OSPAR Convention]; in the Mediterranean Sea Region, see Convention for the Protection of the Mediterranean Sea Against Pollution (with annex and Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft and Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency), 16 February 1976 1102 UNTS 27 (12 February 1978). Available at: https://treaties.un.org/pages/showDetails.aspx?objid=08000002800f6a1c [Barcelona Convention].

This Chapter is divided into three Parts; the first part discusses the governance regime for marine geoengineering in the Baltic Sea Region, the second part focuses on the governance regime on geological carbon sequestration in the North-East Atlantic region, and the final part discusses marine geoengineering governance in the Mediterranean Sea region.

4.1 Regional Governance of Marine Geoengineering in the Baltic Sea

Geoengineering activities like ocean fertilization could face stiff opposition in the Baltic Sea Region. Eutrophication is one of the leading environmental challenges faced by the region.[609] It is caused by the excess introduction of nitrogen and phosphorus compounds into the ocean.[610] Marine geoengineering techniques like ocean fertilization which involves the use of macronutrients like nitrogen and phosphorus to stimulate phytoplankton growth could pose a risk to the eutrophication challenge faced by the region.

A complex environmental governance arrangement governs marine governance in the Baltic Sea region. The general marine governance framework in the region is characterized and challenged by national, international, European, and transnational governance regimes.[611] Besides these multilayered environmental governance arrangements, the regional governance framework is also supported by regional international treaties like the Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) and the Baltic Sea Action Plan.[612]

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[609] Michael Gilek et al., “Environmental Governance of the Baltic Sea: Identifying Key Challenges, Research Topics and Analytical Approaches” in *Environmental Governance of the Baltic Sea* (Switzerland: Springer International Publishing AG, 2016) at 1.
[610] Ibid., 22.
[611] Liliana B. Andonova and Ronald B. Mitchell, “The (1) Rescaling of Global Environmental Politics” (2010) 35 Annual Review of Environmental Resources 255-282.
[612] See, Helsinki Convention, Art. 1; HELCOM, “Baltic Sea Action Plan” 2021 update, available at: https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf. [Baltic Sea Action Plan], preamble; Michael Gilek et al., *supra* note 575 at 7.

The next part discusses the governance of marine geoengineering in the Baltic Sea region by drawing on the role of the Helsinki Convention, the Baltic Sea Action Plan, and the European Union (EU) directive on the geological storage of carbon dioxide.

4.1.1 Regulation of Carbon Storage Activities by the Helsinki Convention

The Coastal States of the Baltic Sea Region comprises eight European Union member States and Russia. The EU member countries in the region are Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, and Sweden.[613] This means that the rules, directives, and guidelines of EU on the protection and preservation of the marine environment apply within the Baltic Sea region, particularly to the eight EU member countries.[614]

The EU establishes and implements international environmental standards among its members, including its members constituting the coastal states of the Baltic Seas. The policy of EU on the environment is to "[preserve, protect, and improve] the quality of the environment… [and promote] measures at the international level to deal with regional or worldwide environmental problems, and in particular combating climate change."[615] Thus, the EU promotes measures instituted by global international agreements[616] and other regional agreements including the Helsinki Convention[617] which seek to deal with climate change.

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[613] HELCOM, "Baltic Sea", available at: http://stateofthebalticsea.helcom.fi/in-brief/our-baltic-sea/#:~:text=Our%20Baltic%20Sea,-Home%20In%20brief&text=The%20Baltic%20Sea%20is%20surrounded,a%20source%20of%20human%20livelihood.

[614] David Langlet, "Using the Continental Shelf for Climate Change Mitigation: A Baltic Sea Perspective" *supra* note 582 at 174.

[615] Treaty on the Functioning of the European Union [2008] OJ C115/47 (TFEU), Art. 191(1).

[616] The European Union (EU) is not a Party to the London Convention and London Protocol as of 23 May 2023. However, most of its members in the Baltics are members of both Convention and Protocol.

[617] The EU is a party to the Helsinki Convention, the first Regional Seas Convention addressing marine pollution. The original Helsinki Convention was passed in 1974 and was later amended in 1992. For extensive discussion of the Helsinki Convention, see Alan Boyle & Catherine Redgwell, *supra* note 474 at 552.

The EU and its members are parties to multilateral treaties that govern marine geoengineering activities. The EU is a party to UNCLOS[618] and UNFCCC[619], thus it is bound by the legal obligations set out by these multilateral agreements.[620] Additionally, the London Protocol applies to its members in the region (apart from Latvia and Lithuania all other EU members within the Baltic Sea region have ratified the London Protocol)[621] thereby compelling the EU to promote the obligations established by the Contracting Parties to the London Protocol in line with its policy to deal with climate change.[622]

It is important to note that all agreements, including regional agreements concluded by the EU become legally binding on its members.[623] The EU is a party to the Helsinki Convention. and the obligations and standards established by the Convention are binding on the EU and its members.[624] In effect, the Helsinki Convention becomes a part of the legal order of the EU and its member States,[625] and takes precedent over EU directives and regulations.[626] Furthermore, the status of the Helsinki Convention is equated to 'applicable international rules and standards' as it represents regional marine environmental law-making and enforcement.[627]

The Helsinki Convention is the operative treaty governing all activities within the marine environment of the Baltic Sea.[628] The Helsinki Convention has been ratified by all the Coastal

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618 See UNCLOS.
619 See UNFCCC.
620 Based on the doctrine of *pacta sunt servanda* the European Union is obligated to implement all its obligations under UNCLOS and UNFCCC.
621 International Maritime Organization, "Ratification by State", online: https://www.imo.org/en/About/Conventions/Pages/StatusOfConventions.aspx.
622 The European Union is not a party to the London Protocol, but most of its coastal members in the Baltic Seas region are signatories.
623 Treaty on the Functioning of the European Union [2008] OJ C115/47 (TFEU), *supra* note 3, Art. 216(1).
624 Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, and Sweden.
625 David Langlet, "Using the Continental Shelf for Climate Change Mitigation" *supra* note 582, at 179.
626 Ibid.
627 UNCLOS, Art.197; Henrik Ringbom et al., "Combatting Eutrophication in the Baltic Sea: Legal Aspects of Sea-Based Engineering Measures: Legal Perspective (Leiden: Brill NV, 2019), at 17.
628 Helsinki Convention, Art. 1.

States in the Baltic Sea region.[629] It establishes the Baltic Marine Environment Protection Commission (HELCOM)[630] which aims to increase the resilience of the ecosystem of the Baltic Sea to the impacts of climate change.[631] The Convention applies to the protection of the marine environment of the Baltic Area, comprising of the waterbody and the seabed including all living organisms in it.[632] The protection extends to all activities that could adversely impact the Baltic Sea marine environment including marine geoengineering activities.[633]

The Convention incorporates many of the Rio principles and urges the Contracting States to implement the obligations of the Convention.[634] The fundamental obligations of Contracting Parties include taking necessary legislative, administrative, or other relevant measures to prevent and eliminate pollution in the Baltic Sea.[635] It urges Contracting Parties to apply a precautionary approach in instances where they seek to introduce substances or energy into the ocean when there is no conclusive evidence of a causal relationship between inputs and their alleged effects.[636] The duty to take precautionary measures extends to marine geoengineering activities because there is no conclusive evidence of the impacts each activity could have on the marine environment.[637]

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629 See Helsinki Convention.
630 Helsinki Convention, Art. 19(1).
631 Baltic Sea Action Plan, *supra* note 612.
632 Helsinki Convention, Art. 4(1).
633 Marine geoengineering activities have a range of adverse effects that could affect the marine environment. See Chapter Two for an extensive discussion of each marine geoengineering activity and their impact on the marine environment.
634 Alan Boyle & Catherine Redgwell, *supra* note 474 at 552.
635 Helsinki Convention, Art. 3(1).
636 Helsinki Convention, Art. 3(2). It implies that marine geoengineering activities such as ocean upwelling, which uses the marine resources found in the Baltics, may be permitted. However, considering there is no conclusive evidence of the sequestration potential and impacts of ocean upwelling, such an activity must be carried out with precaution.
637 See GESAMP, *supra* note 53 at 12. The Working Group found that there needed to be more knowledge available to make air-tight decisions relevant to policy formulation or governance of the activity.

The Contracting Parties are mandated to avoid introducing harmful substances into the Baltic Sea. The Convention urges Contracting Parties to prevent and eliminate pollution of the marine environment of the Baltic Sea Area caused by harmful substances and implement the procedures and measures set out in Annex I.[638] It defines "harmful substance" as any substance, which, if introduced into the sea can cause pollution.[639] According to Henrik Ringbom et al. the definition of harmful substances and the criteria listed in Annex I of the Convention presupposes that harmful substances include any substance capable of causing pollution including anthropogenically produced substances capable of causing eutrophication such as nitrogen and phosphorus compounds.[640] Thus, marine geoengineering activities that introduce nitrogen and phosphorus compounds into the ocean are harmful substances by the dictates of the Helsinki Convention.

UNCLOS and the London Protocol encourage regional arrangements for the control of dumping.[641] The Helsinki Convention prohibits dumping in the Baltic Sea Area.[642] Any 'deliberate disposal at sea or into the seabed of wastes or other matter from ships, other man-made structures at sea or aircraft' is deemed as dumping.[643] Like the London Protocol, it excludes the placement of matter for a purpose other than the mere disposal provided it is not contrary to the aims of the Helsinki Convention.[644] Thus, the Convention prohibits the injection of carbon dioxide in the Baltic Sea because the carbon dioxide is not likely to be retrieved.[645]

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[638] Helsinki Convention, Art. 5.
[639] Helsinki Convention, Art. 2(7). The definition of 'harmful substance' is broad to cover the storage of carbon and marine geoengineering activities such as ocean fertilization which introduces compounds to boost phytoplankton populations for carbon sequestration.
[640] Henrik Ringbom et al., *supra* note 559.
[641] See UNCLOS, Art. 197; London Protocol, Art. 8; Alan Boyle & Catherine Redgwell, *supra* note 474 at 519.
[642] Helsinki Convention, Art. 11(1).
[643] Helsinki Convention, Art. 2(4)(a).
[644] Helsinki Convention, Art. 2(4)(b)(ii).
[645] David Langlet, "Using the Continental Shelf for Climate Change Mitigation: A Baltic Sea Perspective" *supra* note 582, at 181.

4.1.2 The Baltic Sea Action Plan on Carbon Storage Activities in the Baltic Sea

At the 2018 Brussel Ministerial Meeting, it became apparent to the parties to adopt a robust action plan that will address new environmental issues in addition to existing commitments made in the 2007 Action Plan. The Baltic Sea Action Plan[646] was initially adopted by the Contracting Parties to the Helsinki Convention in Poland in 2007.[647] The 2007 Action Plan set targets to establish a good ecological status by 2021.[648] However, by 2018 it became apparent to the Parties that the overall goal of the 2007 Action Plan to reach good environmental status by 2021 will not be achieved, thereby prompting the Parties to adjust its target and consider previously unaddressed challenges.[649]

The Action Plan identifies eutrophication as the leading environmental threat to the Baltic Sea.[650] The Baltic Sea is nourished with nutrients through two means: from natural sources such as connecting rivers and the air and from human activities in the sea and on land.[651] Eutrophication is caused by an excess introduction of macronutrients such as nitrogen and phosphorus into the ocean.[652] Geoengineering techniques such as ocean fertilization which involves the introduction of nitrogen or phosphorus into the ocean could face stiff opposition in the Baltic Seas region because of the eutrophication concerns in the region.

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646 Baltic Sea Action Plan, *supra* note 631.
647 Alan Boyle & Catherine Redgwell, *supra* note 474 at 552.
648 Baltic Sea Action Plan, *supra* note 631 at 6.
649 See, HELCOM, "Implementation of the 2007 Baltic Sea Action Plan" (2021). Available at: https://helcom.fi/wp-content/uploads/2021/10/Implementation-of-the-2007-BSAP-v6-211012.pdf., 4. The 2007 Action Plan was segregated into four parts: eutrophication, hazardous substances, biodiversity and nature conservation, and maritime activities.
650 Ibid., 20.
651 Ibid. The river is the primary source of both nitrogen and phosphorus.
652 Ibid.

The Action Plan sets targets to minimize eutrophication in the region. It sets a ceiling of 792,209 tons of nitrogen and 21,7716 tons of phosphorus annually as the ceiling of allowable macronutrients in the region.[653] It estimates that it will take decades to achieve the eutrophication targets set by the Action Plan and that it will involve the utilization of the best available scientific knowledge and the application of the HELCOM seabed measures to manage internal nutrient reserves[654].[655]

The Action Plan sets targets and measures for sea-based activities in the Baltic Sea to ensure that the activities are environmentally sustainable. The Action Plan defines the sea-based activities to cover all human operations and construction at sea, including commercial shipping and recreational boating to fisheries, construction work, dredging, energy production, and the extraction of natural resources. It notes that activities such as dredging, other forms of marine energy production, laying of underwater cables and pipelines have adverse effects such as the physical disturbance and loss of the Baltic seabed.[656] It further states that submerged hazardous objects remain a physical obstacle on the seafloor and affect marine organisms such as sea birds.[657] It institutes measures to curtail the disturbance of the seabed by prohibiting the introduction of non-indigenous species into the Baltic Sea, minimizing the inputs of nutrients, hazardous substances and litter from seabed activities, among others.[658] Marine geoengineering

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[653] Ibid., 21. The Baltic Sea Action Plan uses the Net Nutrient Input Ceiling (NIC) to measure the maximum allowable inputs in each sub-basin. See the Baltic Sea Action Plan, *supra* note 631.
[654] HELCOM, "Guidelines for Sea-Based Measures to Manage Internal Nutrient Reserves in the Baltic Sea Region" (October 2021). Available at: https://helcom.fi/wp-content/uploads/2021/10/Guidelines-for-Sea-Based-Measures-to-Manage-Internal-Nutrient-Reserves-in-the-Baltic-Sea-Region.pdf. [HELCOM Guidelines for Sea-Based Measures].
[655] Ibid. The Baltic Sea Action Plan lists measures to ensure the promotion of its objectives. The Plan spans agriculture and nutrient recycling. However, the measures do not explicitly mention marine geoengineering activities. See ibid, at 23 and 24.
[656] Ibid., 38.
[657] Ibid. The proposal to store carbon dioxide in Geosynthetic containers, as proposed Capron et al. constitutes a physical object that could affect marine life. See Mark E. Capron et al., *supra* note 116.
[658] Ibid., 40.

activities such as artificial downwelling and ocean thermal energy conversion (OTEC) involve the use of pipes poses physical and biological danger to fishes and other marine species including obstructing communication or predator/prey dynamics in the marine environment.[659] The use of geosynthetic containers as proposed by Capron et al[660] could pose physical obstacles on the seafloor which affects marine life.[661]

The Action Plan does not discuss marine geoengineering activities but sets targets for other natural carbon sequestration processes like natural blue carbon processes. It urges member States to enhance the understanding of the role of the Baltic Sea in mitigating atmospheric concentration of carbon dioxide sustainably using natural blue carbon processes.[662] Additionally, it insists that member States enhance their understanding of the carbon cycle of the Baltic Sea land-sea system including carbon sequestration through biodiversity.[663]

Thus, even though the Action plan does not expressly govern marine geoengineering activities, it delineates activities that are likely to have adverse effects on the marine environment, including activities that constitute some marine geoengineering activities.

4.1.3 The Role of the European Union Directive on Carbon Storage in the Baltic Sea Region

The EU has adopted a legal framework for capturing and storing carbon. The EU and its members adopted Directive 2009/31/EC (the "Directive") to regulate the capture and storage of carbon dioxide.[664] According to David Langlet, this Directive is the most elaborate legal

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659 Shylesh Muralidharan, *supra* note 271.
660 Mark E. Capron et al., *supra* note 116.
661 Ibid.
662 Ibid., 51.
663 Ibid.
664 Directive 2009/31/EC of the European Parliament and of the Council on the Geological Storage of Carbon Dioxide and Amending Council Directive 85/337/ EEC, European Parliament and Council Directive 2000/60/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC, and Regulation (EX) No 1013/2006 [2009] OJ L140/114. Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF.

framework globally.[665] The Directive establishes a legal framework for the environmentally safe geological storage of carbon dioxide to contribute to addressing climate change.[666] It applies to the geological storage of carbon dioxide in the territories of EU member states including their exclusive economic zones and continental shelves.[667] The Directive does not apply to a couple of geological storage of carbon dioxide activities including the geological storage of carbon dioxide with a total intended storage below 100 kilotons undertaken for research, development or testing of new products and processes;[668] the geological storage of carbon dioxide in a site with a storage complex extending beyond the exclusive economic zones and continental shelves of member states;[669] and the storage of carbon dioxide in the water column.[670]

The Directive establishes an elaborate permit regime for the storage of carbon. It establishes a storage permit regime that requires Member States to ensure that they do not carry out any carbon storage without a valid storage permit.[671] It lists the minimum information that must be present in an application for storage[672] and sets out the threshold and parameters within which the competent authority shall issue the storage permit.[673] Additionally, where an application identifies that exploration activities are necessary to generate the relevant information for geological carbon dioxide site selection, it shall ensure that an exploration permit is issued before the conduct of any exploration activity.[674] All Member States are also required to

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[665] David Langlet, "Using the Continental Shelf for Climate Change Mitigation" *supra* note 582, at 180.
[666] Directive 2009/31/EC, *supra* note 24, Art. 1(1).
[667] Directive 2009/31/EC, Art. 2(1).
[668] Directive 2009/31/EC, Art. 2(2). The exclusion of carbon storage activities below 100 kilotons undertaken for research purposes is at variance with the London Protocol, which mandates States to carry out only small-scale legitimate scientific research. See International Maritime Organization (IMO) Resolution LP.1(1).
[669] Directive 2009/31/EC, Art. 2(3).
[670] Directive 2009/31/EC, Art. 2(4).
[671] Directive 2009/31/EC, Art. 6.
[672] Directive 2009/31/EC, Art. 7.
[673] Directive 2009/31/EC, Art. 8.
[674] Directive 2009/31/EC, Art. 5.

ensure that the operator monitors the injection facilities, storage complex and the surrounding environment to detect leakages, migration of carbon dioxide, among others.[675]

The Directive imposes an obligation on the operator of a carbon sequestration facility to report significant irregularities, including carbon leakages to the relevant authorities.[676] It establishes measures that must be carried out in the event of carbon leakages or significant irregularities.[677] The operator is required to notify the competent authority of any leakage or significant irregularities and is mandated to take corrective measures including protecting human health.[678]

The Directive lists the circumstances under which a storage site shall be closed. It provides that a storage site will cease to operate under the following circumstances: where the operator fails to meet the relevant conditions stated in the permit; at the substantiated request of the operator, after authorization by the competent authority; and where the competent authority decides to withdraw the permit after it is proven that it is riskier to continue with the project.[679] Even when the site is closed, the operator must monitor, report, and take corrective measures on the site until the responsibility of the storage site is transferred to the competent authority.[680]

The need to allocate liability arises from the storage site closure. The Directive transfers liability from the operator to the authority under limited conditions. It stipulates that the operator can transfer liability associated with the storage site to the competent authority only when the following conditions are met: "(a) all available evidence indicates that the stored CO_2 will be completely and permanently contained; (b) a minimum period, to be determined by the

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[675] Directive 2009/31/EC, Art. 13.
[676] Directive 2009/31/EC, Art. 16(1).
[677] Ibid.
[678] Ibid.
[679] Directive 2009/31/EC, Art. 17(1).
[680] Directive 2009/31/EC, Art. 17(2).

competent authority has elapsed. This minimum period shall be no shorter than 20 years unless the competent authority determines that the criterion referred to in point (a) is complied with before the end of that period; (c) the financial obligations referred to in Article 20 [of the Directive] have been fulfilled; (d) the site has been sealed and the injection facilities have been removed."[681]

The Directive imposes financial obligations on the operator before and after geological carbon dioxide storage. According to Article 19 of the Directive, Member States are to ensure that there is adequate financial security or any other equivalent deposited by the potential operator as part of the application for a storage permit process.[682] The rationale for the security deposit is to ensure the compliance of all obligations arising under the issued permit, including the decommissioning of the project, post decommissioning obligations, as well as any obligations arising out of the storage.[683] Furthermore, an obligation is imposed on Member States to ensure that the operator makes a financial contribution to the competent authority before transferring responsibility to the latter.[684] The criteria to determine the value of the contribution include an obligation on Member States to ensure that the contribution is capable of covering at least the anticipated cost of monitoring the disused project for 30 years.[685]

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681 Directive 2009/31/EC, Art. 18(1).
682 Directive 2009/31/EC, Art. 19(1).
683 Ibid.
684 Directive 2009/31/EC, Art. 20(1).
685 Ibid.

4.1.4 European Union Directive on Carbon Storage and its Implications on the Baltic Sea Regional Seas Programme.

All carbon storage permits to be issued pursuant to the EU Directive that increases the risk of eutrophication in the Baltic Sea contravenes the aims of the Helsinki Convention. The Contracting Parties to the Helsinki Convention are required to prevent and eliminate pollution of the Baltic Sea caused by harmful substances from all sources and to implement the procedures and measures of Annex 1.[686] The Convention classifies harmful substances to include substances that could anthropogenically cause the risk of eutrophication.[687] Thus, carbon sequestration techniques such as ocean fertilization which introduce macronutrients like iron, nitrogen, and phosphorus could cause eutrophication,[688] thereby making ocean fertilization activities contrary to the aims of the Helsinki Convention and the aim of the Baltic Sea Action Plan. To the extent that the prohibited forms of carbon sequestrated activities under the EU Directive do not include ocean fertilization,[689] any permit issued for ocean fertilization activity in accordance with the EU Directive in the Baltic Sea contravenes the Helsinki Convention and the Baltic Sea Action Plan. According to David Langlet, it remains problematic to permit EU member States to violate a

[686] Helsinki Convention, Art. 5.
[687] Helsinki Convention, Annex I, Part 1.1.
[688] Karen N. Scott, "Engineering the 'Mis-Anthropocene': International Law, Ethics and Geoengineering" (2015) 29:1 Ocean Yearbook 61-84 at 67 [Karen N. Scott, "Engineering the 'Mis-Anthropocene'"]; A. Oschlies et al., "Side Effects and Accounting Aspects of Hypothetical Large-Scale Southern Ocean Iron Fertilization" (2010) 7 Biogeosciences 4017 -4035 at 4026; The Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) of the Convention on Biological Diversity (CBD) noted that if ocean fertilization is carried out at a significant scale may increase the risk of harmful algal blooms, and increased benthic biomass, see, CBD Secretariat, Technical Series No. 66, *supra* note 183.
[689] The EU Directive prohibits three forms of carbon sequestration in the ocean: geological storage of carbon with a total intended storage below 100 kilotons; a storage site with a storage complex extending beyond the territory of Member States, including their maritime jurisdictions; and storage in the water column.

higher EU norm in the form of the Helsinki Convention should a permit be issued according to the Directive.[690]

Besides, developments made by Contracting Parties to multilateral agreements such as the London Protocol, CBD, and the Baltic Sea Action Plan are essential in streamlining the European Union Directive to ensure it complies with regional and global obligations. The Contracting Parties to the London Convention and London Protocol since 2006 have passed resolutions prohibiting marine geoengineering activities with the exclusion of small-scale legitimate scientific research which is not contrary to the aim of the Convention.[691] Unlike the Directive, the London Convention and London Protocol adopt a reverse listing approach by prohibiting all marine geoengineering activities except legitimate scientific research experiments which is not contrary to the aims of the Protocol.[692] Further, per decisions X/33 and XI/20, the Contracting Parties to CBD ensured that no marine geoengineering activity takes place in the absence of "science-based, global, transparent, and effective control and regulatory mechanisms for geoengineering".[693] Most of the EU countries located in the Baltic Sea region are parties to the London Protocol, thus are expected to comply with the resolutions adopted under the London Convention and London Protocol. Currently, the EU Directive remains a regional directive, thus cannot be regarded as a 'global' control and regulatory mechanism for geoengineering in accordance with decisions X/33, XI/20, and LP.4(8) of the London Convention and London

[690] David Langlet, "Using the Continental Shelf for Climate Change Mitigation" supra note 582, at 181; David Langlet, "Exporting CO2 for Sub-Seabed Storage: The Non-Effective Amendment to the London Dumping Protocol and its Implications" (2015) 30 International Journal of Marine and Coastal Law 395-417, at 181.
[691] See Chapter Three, which traces the evolution of the regulation of marine geoengineering activities under the London Convention and London Protocol by the Contracting Parties.
[692] Grant Wilson, *supra* note 478 at 534.
[693] See CBD Secretariat, Decision X/33 *supra* note 39; CBD, UNEP/COP/DEC/XI/20, *supra* note 457.

Protocol.[694] Furthermore, in lieu of EU's policy to take measures adopted at global and regional levels in combating climate change, the EU is expected to ensure that its Directives are in consonant with regional commitments including the Baltic Sea Action Plan.

4.2 Governance of Marine Geoengineering in the North-East Atlantic

The North-East Region has developed a governance framework for the geological storage of carbon dioxide in the ocean. A regional treaty and a risk assessment guideline that serves as a crucial tool in governing marine geoengineering is essential to govern marine geoengineering activities in the North-East Atlantic region. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)[695] and the OSPAR Guidelines for Risk Assessment and Management of Storage of CO2 Streams in Geological Formations (OSPAR Guideline for Risk Assessment)[696] constitutes regional efforts to regulate human activities which seek to use the ocean as a storage hub for carbon dioxide.

4.2.1 The OSPAR Convention and Atmospheric Carbon Dioxide Storage Activities in the North-East Atlantic

The OSPAR Convention applies to the North-East Atlantic Sea region. OSPAR Convention governs a large area of the ocean, stretching from the Mid-Atlantic Ridge in the west to the

[694] It must be streamlined to reflect the Assessment Framework established by Resolution LP.4(8) the Contracting Parties to the London Protocol developed to assess placement activities, including ocean fertilization activities deemed legitimate scientific research.
[695] See, OSPAR Convention *supra* note 608.
[696] OSPAR Commission, *OSPAR Guideline for Risk Assessment and Management of Storage of CO2 Streams in Geological Formations,* Reference Number: 2007-12. Available at: https://www.ospar.org/documents?d=32760. [OSPAR Guideline for Risk Assessment].

North Sea in the east and from the North Pole southwards to the Azores.[697] OSPAR is a collaborative framework involving 15 Governments and the European Union that aims to safeguard the marine environment of the North-East Atlantic.[698]

The Convention was adopted to serve as a comprehensive regional instrument capable of protecting and preserving the North-East Atlantic and Arctic marine environment from pollution.[699] The Contracting Parties adopted the Convention to merge the 1972 Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (the Oslo Convention)[700] which regulated ocean dumping and incineration, and the 1974 Convention for the Prevention of Marine Pollution from Land-Based Sources (the Paris Agreement of 1974) which regulated marine pollution from land-based sources, the atmosphere, and from offshore oil and gas activities.[701] It is a regional agreement that protects the marine environment of the North-East Atlantic.[702] It establishes general obligations urging all Contracting Parties to protect and eliminate pollution and institute all measures to protect the maritime area against the adverse effects of human activities.[703]

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[697] United Nations Environment Programme, "North-East Atlantic", available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/north-east?_ga=2.71224272.1182785317.1685373426-2059025123.1684457857. [UNEP, "North-East Atlantic"]

[698] Ibid. The fifteen countries are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom. See, OSPAR Commission, "About OSPAR", available at: https://www.ospar.org/about#:~:text=OSPAR%20is%20the%20mechanism%20by,the%20Paris%20Convention%20of%201974. [OSPAR Commission].

[699] Louise de La Fayette, "The OSPAR Convention Comes into Force: Continuity and Progress" (1999) 14:2 t*he International Journal of Marine and Coastal Law* 247-297 at 250.

[700] Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, 15 February 1972, 932 UNTS 3 (7 April 1974). OSPAR started with the Oslo Convention against dumping and was subsequently extended to address land-based sources of marine pollution and the offshore industry covered by the Paris Convention of 1974. UNEP, "North-East Atlantic", *supra* note 696; OSPAR Commission, *supra* note 663.

[701] Louise de La Fayette, *supra* note 698.

[702] Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/29, *supra* note 368 at 39.

[703] OSPAR Convention, Art. 2(1).

The Convention establishes the OSPAR Commission, which implements the Convention within the region. According to Article 10 of the Convention, the OSPAR Commission comprises the representatives of each of the Contracting Parties[704] and it superintends over the implementation of the Convention and design programs and measures for the prevention and elimination of pollution, as well as control activities which could adversely impact the marine environment of the North-East Atlantic.[705]

OSPAR Convention permits the storage of carbon dioxide streams in geological formations of the North-East Atlantic. Prior to the inroads made by the Contracting Parties to CBD and the London Convention/London Protocol in terms of marine geoengineering, the OSPAR Convention had been amended by the Contracting Parties to permit the storage of carbon dioxide in sub-soil geological formation of the ocean in 2007.[706] The amendment excludes the storage of carbon dioxide into a sub-soil geological formation in North-East Atlantic from the dumping regime of OSPAR under certain circumstances.[707] Carbon dioxide streams from carbon dioxide capture processes for storage are excluded from the dumping regime provided: "(i) disposal is into a sub-soil geological formation; (ii) the streams consist overwhelmingly of carbon dioxide;[708] (iii) no wastes or other matter are added for the purpose of disposing of those wastes or other matter; (iv) they are intended to be retained in these

[704] OSPAR Convention, Art.10(1).
[705] OSPAR Convention, Art. 10(2)(a) and (c).
[706] OSPAR Commission, *Amendments of Annex II and Annex III to the Convention in relation to the Storage of Carbon Dioxide Streams in Geological Formations*, ANNEX 4 (Ref. §2.10a), OSTEND: 25-29 JUNE 2007, available at: https://www.ucl.ac.uk/cclp/pdf/OSPAR2007-Annex-4.pdf. [OSPAR Commission, Amendments of Annex II and III].
[707] Ibid., at Annex II Art. 3(1)(2)(f).
[708] However, the carbon streams may contain incidental substances from the source material and the capture, transport, and storage processes used.

formations permanently and will not lead to significant adverse consequences for the marine environment, human health, and other legitimate uses of the maritime area.” [709]

The amendment made to the OSPAR Convention is in force and applies to all Contracting Parties that have ratified, accepted, or approved it. According to Article 15, all amendments made to the Convention shall enter into force for Contracting Parties which have ratified, accepted, or approved the amendment on the thirtieth day after receipt by the Depositary Government (Government of the French Republic[710]) of notification of its ratification, acceptance, or approval by at least seven Contracting Parties.[711] However, the amendment shall be legally binding on any other Contracting Party that subsequently deposits its ratification, acceptance, or approval after the entry into force of the amendment on the thirtieth day after that Contracting Party has deposited its instrument of ratification, acceptance, or approval with the Depository Government. As of 23 July 2011, Denmark, European Union,[712] Germany, Luxembourg, Norway, Spain, and the United Kingdom had ratified and deposited their instruments of ratification with the Depository Government.[713] Subsequently, the amendments entered into force for the Netherlands.[714]

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[709] OSPAR Commission, Amendment of Annex II and III, at Annex II Art. 3(1)(2)(f).
[710] OSPAR Convention, Art. 26.
[711] OSPAR Convention, Art. 15(5).
[712] The European Union is a member of the OSPAR Convention, which implies that all EU members must comply with Directive 2009/31/EC and the OSPAR Convention. Although the OSPAR Convention permits carbon storage in geological formations subject to certain conditions, Directive 2009/31/EC could complement and further operationalize the OSPAR Convention within EU Member States.
[713] OSPAR Commission, “Ratification of OSPAR Carbon Capture and Storage Measure”, online: https://www.ospar.org/site/assets/files/1501/ospar_pr_11_ratification_of_ccs_measure_en.pdf.
[714] Ibid.

4.2.2 The Role of the OSPAR Guideline for Risk Assessment in Regulating the Carbon Dioxide Storage

The Contracting Parties decided to establish a permit regime for the storage of carbon dioxide streams in geological formation from carbon dioxide capture processes.[715] The decision by the Parties to establish a permit regime suggests a tacit prohibition of the storage of carbon dioxide streams from carbon dioxide capture processes into geological formations without authorization or oversight by the competent national authorities.[716] All Contracting Parties are required to ensure that all authorizations given by competent national authorities comply with the OSPAR Guidelines for Risk Assessment and Management of Storage of CO2 Streams in Geological Formations (OSPAR Guideline for Risk Assessment).[717] In Tim Dixon et al. view, the permit requirements under OSPAR regime are more extensive compared to the permit regime established under the London Protocol.[718]

The OSPAR Guideline for Risk Assessment contains a generic assessment framework for issuing permits for the storage of carbon dioxide.[719] The scope of the OSPAR Guideline for Risk Assessment is based on the process of carbon dioxide injection and post-injection risks of leakage.[720] The generic assessment framework is found in Annex I of the OSPAR Guideline for

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[715] OSPAR Commission, *OSPAR Decision 2007/2 on the Storage of Carbon Dioxide Streams in Geological Formations*, Annex 6 (Ref. §2.10c), OSTEND: 25-29 JUNE 2007. Available at: https://www.nlog.nl/sites/default/files/decision%202007_2_co2_storage.doc, at para 3.2. [OSCAR Commission, Annex 6].
[716] OSPAR Commission, Annex 6, at para 3.1.
[717] OSPAR Commission, Annex 6, at para 3.1; According to article 2 of Annex IV of OSPAR, Contracting Parties must use and develop other duly validated scientific assessment tools, including risk assessment strategies. Thus, all Parties to OSPAR must comply with the OSPAR Guidelines for Risk Assessment and Management of Storage of CO2 Streams in Geological Formations in such applications. See OSPAR Convention, Art. 2 of Annex IV.
[718] Tim Dixon et al., "International Marine Regulation of CO2 Geological Storage Developments and Implications of London and OSPAR" (2009) 1 Energy Procedia 4503-4510 at 4507.
[719] OSPAR Guideline for Risk Assessment, *supra* note 695 at para. 7.
[720] Ibid., para. 6.

Risk Assessment, which is referred to as the Framework for Risk Assessment and Management of CO2 Streams in Geological Formations (FRAM).[721]

FRAM outlines six stages of assessing the risk associated with a proposal to store carbon dioxide in the North-East Atlantic Sea. It comprises (a) problem formulation; (b) site selection and characterization; (c) exposure assessment; (d) effects assessment; (e) risk characterization; and (f) risk management.[722] Thus, FRAM assists in the management of carbon dioxide storage by assessing injection sites, identifying measures for hazard reduction, examining remediation and mitigation, characterizing risks to the marine environment, and monitoring injection sites.[723]

Besides these proactive steps undertaken in the North-East Atlantic Sea region, in 2008, the Contracting Parties to the OSPAR Convention prohibited the placement of carbon dioxide in water columns or on the seabed.[724] This new development took into consideration the amendments made to the OSPAR Convention which permitted the storage of carbon dioxide streams in geological formations.[725] Nevertheless, the Parties indicated that they are convinced that it is unstainable to store carbon in the water column or on the seabed.[726] The Contracting Parties further raised concerns about the storage methods that are likely to adversely affect living resources and the marine ecosystem, thus making them not viable to climate change mitigation nor compatible with the aims of OSPAR.[727] They decided that the placement of carbon dioxide streams in the water column or on the seabed should be prohibited.[728] However, the Contracting

[721] OSPAR Guideline for Risk Assessment, *supra* note at Annex I.
[722] Ibid., para. 7.
[723] Subsidiary Body on Scientific Technical and Technological Advice, UNEP/CBD/SBSTTA/16/INF/29, *supra* note 368.
[724] OSPAR Commission, *OSPAR Decision 2007/01 To Prohibit the Storage of Carbon Dioxide Streams in the Water Column or on the Sea-bed, OSPAR 07/25/1,* Annex 5, 15 January 2008. Available on: https://www.ospar.org/documents?v=32641. [OSPAR Commission, Annex 5].
[725] Ibid., preamble.
[726] Ibid.
[727] Ibid.
[728] Ibid.

Parties exempted the placement of substances that are in accordance with the aims of the OSPAR Convention and result from normal operations as described in article 1(g)(i) of OSPAR or for a purpose other than the mere disposal as described in article 1(g)(i) of the Convention.[729] The activities in article 1(g)(i) include disposal made in accordance with the London Protocol.[730]

The OSPAR regime establishes a detailed mechanism to regulate the disposal of carbon dioxide into geological structures in the North-East Atlantic. Besides, the amendments to OSPAR Convention, the OSPAR Guideline for Risk Assessment establishes a comprehensive assessment framework like the Generic Assessment Framework provided for in the London Protocol.[731] Thus, the independently administered Regional Seas Programme in the Baltic Sea and North-East Atlantic have been proactive in trying to establish a regime which explicitly regulates the storage of carbon either in the Baltic Sea or the North-East Atlantic Ocean.

4.3 Regional Governance of Marine Geoengineering in the Mediterranean Sea

The Mediterranean Sea can store considerable volumes of carbon dioxide. Due to the higher levels of ocean alkalinity and the ventilation of deep waters over shorter timescales, the Mediterranean Sea is considered one of the regional seas that could store carbon dioxide.[732] However, due to its capacity to store substantial levels of carbon dioxide, the region is prone to

[729] Ibid. The amendment to the London Protocol (LP.4(8)) currently prohibits all ocean fertilization activities except small-scale legitimate scientific research activities. It implies that even though the Contracting Parties to the OSPAR Convention regard the sequestration of carbon on the seabed as being unstainable, the London Protocol is yet to list the placement of carbon on the seabed under Annex 4 of LP.4(8).

[730] Ibid. It remains to be seen whether activities such as the transboundary export of carbon dioxide for disposal in the seabed under the London Protocol fall within the exceptions described as constitution article 1(g)(i) of the OSPAR Convention. For discussion on the transboundary disposal of carbon dioxide under the London Protocol, see International Maritime Organization (IMO) Resolution LP.3(4).

[731] Tim Dixon et al., *supra* note 717 at 4507.

[732] Mediterranean Experts on Climate and Environmental Change (MedECC), *Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future.* First Mediterranean Assessment Report [Cramer, W., Guiot, J., Marini, K. (eds.)] (Marseille, France: Union for the Mediterranean, 2020). Available at: https://www.medecc.org/wp-content/uploads/2021/05/MedECC_MAR1_complete.pdf at 20.

ocean acidification. Ocean acidification is considered one of the five long-term issues facing the region.[733]

The Mediterranean Sea region has witnessed minimal efforts at governing geoengineering activities. The Mediterranean Sea Regional Program is the first regional seas program established by UNEP.[734] Unlike the Baltic Sea, and the North-East Atlantic Region, the Mediterranean Sea region has been passive in developing a governance framework for marine geoengineering. There has yet to be a negotiation of a protocol or amendment to the operative regional convention to ensure the effective governance of these activities. Likewise, the region has yet to adopt a resolution or issue a directive or guideline on geoengineering activities.

4.3.1 The Mediterranean Action Plan and Marine Geoengineering Governance

The Mediterranean is highly susceptible to the impacts of climate change.[735] In the last decades, the region has experienced a sea-level rise, warming days and nights, heat waves, a surge in extreme precipitation and soil dryness, and less chilly days and nights. There are projections of worsening conditions based on climate change.[736] These projections predict an increase in the risk of desertification and soil degradation, sea-level rise, an increase in duration and intensity of droughts, alteration in species compositions, habitat losses, and many other potential adverse effects of climate change.[737]

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[733] Ibid.
[734] Alan Boyle & Catherine Redgwell, *supra* note 474 at 520.
[735] IPCC, Synthesis Report (2014), *supra* note 377; United Nations Environment Programme/ Mediterranean Action Plan, *Mediterranean Strategy for Sustainable Development 2016-2025* (2016). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/7700/-Mediterranean_strategy_for_sustainable_development_2016-2025_Investing_in_environmental_sustainability_to_achieve_social_and_economic_development-20.pdf?sequence=3. [Mediterranean Strategy on Sustainable Development].
[736] Mediterranean Strategy on Sustainable Development, *supra* note 734 at 48.
[737] Ibid.

The Mediterranean Sea is the first UNEP Regional Seas Program. Its implementation relies on the Mediterranean Action Plan..[738] The Mediterranean Action Plan comprises two phases: Phase I (adopted in 1975) and Phase II (adopted in 1995).[739] In 1976, the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention)[740] entered into force to constitute the legal aspect of the Mediterranean Action Plan.[741] The formulation of Phase I of the Mediterranean Action Plan occurred three years after the Stockholm Ministerial Conference.[742] However, in 1992, following the Rio Summit,[743] the Mediterranean Action Plan sought to implement the results of the summit, and situate Agenda 21[744] within the Mediterranean Sea context by establishing Agenda MED 21. These steps resulted in the creation

738 United Nations Environment Programme "Mediterranean: Mediterranean Action Plan". Available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/mediterranean?_ga=2.212304276.1862929123.1685722035-1533237930.1680052584&_gac=1.147079749.1684684490.CjwKCAjw36GjBhAkEiwAKwIWyaCaV4kHZ-EpVOzPmU1HLVEKDAxN4ZJ4XGBQXFEj3RQACtwmitsh3RoCOLUQAvD_BwE. [UNEP Mediterranean Action Plan].

739 Nulifer Oral, *Regional Cooperation and Protection of the Marine Environment under International Law: The Black Sea* (Boston: BRILL, 2013). Three years after the Stockholm Ministerial Conference, the Mediterranean Action Plan I was adopted as a Regional Seas Programme. However, following the 1992 United Nations (UN) Conference on Environment and Development (Earth Summit) in Rio, the results of the summits influenced the adoption of the Action Plan for the Protection of the Marine Environment and Sustainable Development of the Coastal Areas of the Mediterranean (MAP II) on 10 June 1995, see Sofia Frantzi, "What Determines the Institutional Performance of Environmental Regimes? A Case Study of the Mediterranean Action Plan" (2008) 32:4 Marine Policy 618-629 at 619.

740 See Barcelona Convention. The Convention was amended and renamed in 1995 as the Convention for the Protection of the Marine Environment and the Mediterranean Coastal Region. The Protocols adopted under the Convention were also amended: the Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft was renamed the Protocol for the Prevention and Elimination of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea on 10 June 1995, and the Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency was replaced by the Protocol in Cases of Emergency, combating Pollution of the Mediterranean Sea (Prevention and Emergency Protocol) on 25 January 2002. See Ibid., Nulifer Oral, 108.

741 Sofia Frantzi *supra* note 738 at 619.

742 Peter M. Haas and Rodolfo Lewanski, *Saving the Mediterranean: The Politics of International Environmental Cooperation* (New York: Columbia University Press, 1990).

743 Rio Declaration, *supra* note 311.

744 Agenda 21: Programme of Action for Sustainable Development; The Final Text of Agreements Negotiated by Governments at the United Nations Conference on Environment and Development (UNCED), 3-14 June 1992, Rio De Janeiro, Brazil. (New York, NY: United Nations Dept. of Public Information, 1993) Chap. 34. [Agenda 21].

and adoption of the Action Plan for the Protection of the Marine Environment and Sustainable Development of the Coastal Areas of the Mediterranean (Mediterranean Action Phase II).[745]

The Mediterranean Action Plan contains an organizational structure that implements its aims and objectives. The Mediterranean Action Plan's organizational structure comprises four institutions: the Focal Point, the Bureau, the Mediterranean Commission on Sustainable Development, and the Compliance Committee. Six Contracting Parties make up the Bureau, and they guide and advise the Secretariat in the interim period between the biennial meetings.[746] The Focal Point performs supervisory functions by reviewing the progress of output and ensuring the implementation of recommendations at the national level.[747] The Mediterranean Commission on Sustainable Development acts as an advisory body and has been instrumental in integrating the Sustainable Development Goals into the Mediterranean Strategy on Sustainable Development.[748] The Compliance Committee takes stock of the obligations of Contracting Parties under the Barcelona Convention and its Protocols and facilitate and promote the compliance of these obligations.[749]

Regarding the sequestration of carbon in the region, the Action Plan barely makes mention of carbon sequestration activities or marine geoengineering in the region. However, the Action Plan considers the prevention of pollution by dumping as one of its main objectives.

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745 United Nations Environment Programme. *Report of the Ninth Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against Pollution and its Protocols*, UNEP(OCA)/MED IG.5/16. Athens: UNEP; 1995. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi4vIe1-7T_AhW1j4kEHQTIBxsQFnoECAkQAQ&url=https%3A%2F%2Fwedocs.unep.org%2Fbitstream%2Fhandle%2F20.500.11822%2F2972%2F95ig5_16_eng.pdf&usg=AOvVaw02fj31rP0ucG8uUrrT1xmp.
746 UNEP Mediterranean Action Plan, *supra* note 737; Barcelona Convention, Art. 19.
747 UNEP Mediterranean Action Plan, *supra* note 737.
748 The strategic document has six objectives: ensuring sustainable development in marine and coastal areas; promoting resource management, food production, and food security through sustainable forms of rural development; planning and managing sustainable Mediterranean cities; addressing climate change as a priority issue for the Mediterranean; and improving governance in support of sustainable development. See Mediterranean Strategy on Sustainable Development, *supra* note 734.
749 UNEP Mediterranean Action Plan, *supra* note 737; Barcelona Convention, Art. 27.

Thus, it develops commitments at the regional and sub-regional level to curtain marine dumping in the region.[750] At the regional level it stipulates three activities that promote the objectives of the Action Plan.[751] The Coastal States are required to consolidate reports prepared from data collected on permit issuance and dumping activities.[752] The consolidated reports are required to be given to the Contracting Parties to act upon.[753] The Contracting Parties are to develop technical guidelines spelling out disposal methodology and monitoring requirements for disposal sites.[754] Finally, the Contracting Parties are to assess the implementation of the Protocol[755] and consider the efficiency of the measures instituted.[756]

The Mediterranean Sea region has yet to develop a technical guideline that outlines the disposal methodology and site monitoring requirements. Besides the Action Plan stipulating a need to develop a guideline for geological carbon sequestration activities in the region, the region is yet to develop and adopt a guideline for such an endeavor. Notwithstanding that pollution by dumping remains one of the main objectives of the region, the Coastal States and the Contracting Parties have been passive in developing a guideline in this regard that could contribute to achieving this objective in the region.

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[750] UNEP Mediterranean Action Plan, *supra* note 737 Phase II, Appendix I at 117.
[751] Ibid., 124.
[752] Ibid.
[753] Ibid.
[754] Ibid.
[755] The Protocol for the Prevention and Elimination of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea was adopted on 10 June 1995.
[756] UNEP Mediterranean Action Plan, *supra* note 737 Phase II, Appendix I at 124.

4.3.2 Marine Geoengineering Governance in the Mediterranean Sea: The Role of the Barcelona Convention and Regional Cooperation Frameworks

The Barcelona Convention is a framework treaty which stipulates general rules that are subsequently supplemented by detailed protocols and action plans.[757] Presently, seven protocols spell out rules for dumping, specially protected areas and biodiversity, emergency cooperation, land-based pollution, seabed pollution, transboundary movement of hazardous waste, and integrated coastal zone management.[758] Presently, no protocol has been adopted by the Contracting Parties to the Barcelona Convention to regulate marine geoengineering activities.

The Convention prohibits activities that cause pollution in the Mediterranean Sea.[759] It imposes an obligation on all Contracting Parties to take all appropriate measures, both individually and jointly, to address pollution and enhance the marine environment.[760] It defines "pollution" as any activity that introduces substances or energy into the Mediterranean Sea Area including estuaries. It is likely to result in deleterious harmful effects on living resources and marine life, a hazard to human health, a hindrance to marine activities, impairment of quality of use of seawater, and reduction of amenities. [761] In effect, all marine geoengineering activities that introduce substances or energy into the Mediterranean Sea Area and result in any adverse impacts (mentioned in the definition of what constitutes "pollution") are prohibited.[762]

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[757] Alan Boyle & Catherine Redgwell, *supra* note 474 at 520.
[758] See the UNEP website for context. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/31970/bcp2019_web_eng.pdf.
[759] Barcelona Convention, Art. 4(1).
[760] Barcelona Convention, Art. 4(1).
[761] Barcelona Convention, Art. 2(a)
[762] Ibid.

The duty to prevent, abate, combat, and eliminate pollution extends to the duty to take all appropriate measures to address pollution caused by dumping in the Mediterranean Sea Area.[763] The Mediterranean Sea Area covers 'the maritime waters of the Mediterranean Sea proper, including its gulfs and seas, bounded to the West by the meridian passing through Cape Spartel lighthouse, at the entrance of the Straits of Gibraltar, and to the East by the southern limits of the Straits of the Dardanelles between Mehmetcik and Kumkale lighthouses.'.[764] Any activity constituting dumping as defined by the Barcelona Convention is prohibited, and all Contracting Parties are required to take all appropriate measures to prevent, abate, and eliminate pollution of the Mediterranean Sea area by dumping from ships and aircraft or incineration at sea.[765]

Furthermore, techniques such as ocean upwelling fall outside the definition of dumping by the Barcelona Convention. The Convention significantly adopts the definition of "dumping" by the London Protocol. However, unlike the London Protocol, the Convention omits the disposal from platforms or other manufacturing structures at sea.[766] By virtue of the definition of dumping by the Barcelona Convention, all marine geoengineering activities are prohibited, except marine geoengineering activities that entail the use of dredged materials or organic materials from the processing of other marine organisms.[767] In effect, the dumping provisions in

[763] Barcelona Convention, Art. 5, 6, 7, 8, and 9.
[764] Barcelona Convention, Art. 1(1).
[765] Barcelona Convention, Art. 5.
[766] The definition of dumping under the Protocol is like the London Protocol. However, it does not mention disposal from platforms or other manufactured structures at sea. Additionally, it does not include any abandonment or toppling at the site of platforms or other manufactured structures at sea for the sole purpose of deliberate disposal. See the Convention for the Protection of the Mediterranean Sea Against Pollution (with annex and Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft and Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency), 16 February 1976 1102 UNTS 27 (12 February 1978), Art. 3(3); London Protocol, Art. 1(4).
[767] Barcelona Convention, Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, Art. 5.

the Convention do not apply to marine geoengineering techniques like ocean upwelling, which stimulates the ocean's capacity to store carbon using nutrients within the Mediterranean Sea.

The Convention imposes a duty on the Contracting Parties to design criteria, guidelines, and procedures for dumping activities which the Convention has exempted.[768] The Protocol establishes a permit regime for dumping at sea for activities which the Convention has not prohibited.[769] The permit regime under the Convention establishes the factors that must be taken into consideration before a permit is issued and these factors include, the characteristics and composition of the substance, the characteristics of the dumping site and method to be used, among others.[770] The Contracting Parties are also required to establish criteria, guidelines, and procedures for dumping wastes or other matter permitted under the Convention.

Moreover, the Barcelona Convention establishes other general obligations governing marine geoengineering activities in the Mediterranean Sea. The negotiation of the Convention occurred at the period when geoengineering was yet to become a topical issue. However, it contains provisions that can regulate marine geoengineering activities.[771] For instance, article 13 requires Contracting Parties to promote the research on environmentally sound technology and cooperate in the formulation, establishment, and implementation of clean production

[768] Barcelona Convention, Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, Art. 5.
[769] Barcelona Convention, Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, Art. 5(1) and Annex.
[770] Barcelona Convention, Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, Annex.
[771] See Cesare Marchetti, *supra* note 35; National Academy of Sciences *Policy, Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (2009: National Academy Press, Washington); Paul J. Crutzen, *supra* note 38.

processes,[772] yet it remains an uncertainty whether marine geoengineering is an 'environmentally sound technology'.[773]

Furthermore, the Mediterranean region addresses environmental issues using a regional cooperation framework, notable among them is the Mediterranean Strategy on Sustainable Development (MSSD).[774] The Mediterranean Strategy on Sustainable Development aims to harmonize socio-economic and environmental goals, streamline international commitments to regional conditions, facilitate regional cooperation among stakeholders in implanting the sustainable development goals, and guide national sustainable development strategies. [775] MSSD comprises six objectives, and addressing climate change is deemed a priority issue for the Mediterranean.[776]

MSSD does not explicitly include marine geoengineering as part of its strategic direction. At the regional level, MSSD identifies the promotion of a Mediterranean research agenda on climate change by collaborative programs and networking amongst research centers and universities.[777] At the national level, the strategic documents hope to accelerate the uptake of climate-smart and climate-resilient responses including the design, finance, and implementation of national technology investment plans for climate change.[778]

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[772] Clean Production Method is defined as 'those which reduce or avoid the generation of hazardous wastes in conformity with article 5 and 8 of [the] Protocol'. See Barcelona Convention (Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal Hazardous Wastes Protocol), Art. 1(i).
[773] Barcelona Convention, Art. 13(2).
[774] Mediterranean Strategy on Sustainable Development, *supra* note 734.
[775] Ibid., 19.
[776] Ibid., 48.
[777] Mediterranean Strategy on Sustainable Development, *supra* note 734 at 51.
[778] Ibid., 52.

The Mediterranean Sea region remains one of the most susceptible regional seas to climate change.[779] The Barcelona Convention, being a framework treaty, allows it to adopt protocols to give effect to the general obligations of states stipulated by the Convention. So far, attempts have yet to be made to negotiate an agreement to govern the sequestration of carbon dioxide in the region. Neither has there been any attempt to amend the Barcelona Convention to permit or prohibit carbon dioxide sequestration in the Mediterranean Sea, as observed in the case of the OSPAR Convention.

[779] Ibid.

CHAPTER FIVE: GOVERNANCE OF MARINE GEOENGINEERING IN THE WEST AFRICAN REGION

Climate change poses a risk to the West African sub-region. The West African region comprises the countries of Benin, Burkina Faso, Cameroon, Cabo Verde, Chad, Cote d'Ivoire, Equatorial Guinea, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo.[780] Agriculture and food security, urbanization, health, water resources, and ecosystem are some of the areas identified by the Working Group of the Intergovernmental Panel on Climate Change to be vulnerable to the impacts of climate change.[781]

These developments necessitate a basis to ascertain the readiness of the West African sub-region to govern this evolving technology effectively. This Chapter has five parts. The first Part traces the region's evolution of geoengineering research and experiments. This Part will highlight CDR and SRM activities commissioned in West African countries such as Cabo Verde, Benin, and Ghana. The next Part discusses the Convention for Cooperation in the Protection, Management, and Development of the Marine and Coastal Environment of the Atlantic Coast of the West and Central Africa Region (Abidjan Convention)[782] considering the legal obligations that arise in respect of engaging in marine geoengineering activities in West Africa. The Abidjan Convention incorporates international rules and standards on ocean dumping, thus creating an avenue for the dumping regime of the London Convention and London Protocol to have effects

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[780] See Britannica, "West Africa'. Available at: https://www.britannica.com/place/western-Africa.

[781] Isabelle Niang et al., *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)] (Cambridge: Cambridge University Press, 2014), Chp. 22.

[782] Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region and Protocol, 23 March 1981, ILM Vol. 20, p. 746-76 Art.1. [Abidjan Convention].

on the Contracting States. The remaining parts examine the contribution of the African Union (AU) and the Economic Community of West African States (ECOWAS) in establishing a governing framework for marine geoengineering activities for the sub-region. Although these efforts by the AU and ECOWAS are not binding, they serve as a crucial springboard to develop binding obligations on African States.

This Chapter connects with the conclusion, where we will conduct a comparative analysis to comprehend the best practices in the Baltic, Mediterranean, and North-East Atlantic Sea regions. These practices may contribute to developing the governance regime for marine geoengineering in West Africa. In this context, we will adopt three indicators for the analysis: the governance approach by regional conventions, the use of soft law instruments to govern geoengineering, and the extent to which Coastal States within the region participate in the global multilateral agreements discussed in Chapter Three.

5.1 Marine Geoengineering Activities in West Africa

Sub-Saharan Africa is vulnerable to the impact of climate change.[783] For instance, studies show that due to the continent's reliance on agricultural activities, climate change exposes the continent to the vagaries of extreme weather conditions in agriculture.[784] Furthermore, others suggest that West-African coasts comprising of Abidjan, Lomé, and Lagos will experience sea level rise between 0.4 meters and 1.15 meter between 2081 to 2100.[785]

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[783] The IPCC predicts that climate change may adversely impact the yields of major cereal crops in Africa. See Isabelle Niang et al., *supra* note 779 at 1221.
[784] David I. Stern, et al., "Temperature and malaria trends in highland East Africa" (2011) 6:9 PloS One e24524-e24524.
[785] Olivia Serdeczny et al., "Climate Change Impacts in Sub-Saharan Africa: From Physical Changes to their Social Repercussions" (2017) 17:6 Regional Environmental Change 1585-1600 at 1589.

Based on the risks posed by climate change, some African countries have proposed to mitigate atmospheric greenhouse gases using geoengineering.[786] It is estimated that out of the fifty-one NDCs submitted by African countries, about seven countries have proposed to adopt geoengineering as part of their international commitment to addressing climate change.[787] And out of the seven countries,[788] two have made commitments to explore the research and deployment of marine geoengineering as one of their climate change mitigation strategies.[789] Conversely, Rwanda regards carbon capture and storage technologies as a 'highly unfeasible option' towards addressing climate change and its impacts.[790]

Two African countries - Cabo Verde and Mauritius - propose using the ocean to engage in carbon capture and storage activities. Cabo Verde proposes to contribute to climate change mitigation by exploring 'ocean-based natural carbon sequestration, which proves harmless to the maritime resources, coastal communities, and sea ecosystems'.[791] Mauritius undertakes to research the potential of aquaculture to sequester carbon, as well as serve as renewable aquatic energy in the form of algal biofuels, hydropower and other aquatic-based energy systems that

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[786] Anja Chalmin, "Geoengineering Projects in Africa Intensify Along with Oil and Gas Expansion" (7 November 2022), available on: https://www.geoengineeringmonitor.org/2022/11/geoengineering-projects-in-africa-intensify-along-with-oil-and-gas-expansion/?print=pdf. [Anja Chalmin, "Geoengineering Projects in Africa Intensify Along with Oil and Gas Expansion"].

[787] Ibid.

[788] Ibid. Malawi proposed to apply carbon capture and storage to future grid-based thermal plants; Lesotho is exploring the widespread deployment of carbon capture and storage technologies; Egypt and South Africa proposed in their initial Nationally Determined Contributions (NDCs) but omitted it in their amended NDCs; Tunisia regards carbon capture and storage technologies as niche technologies which it desires to engage in further research and industrial initiatives; Cabo Verde and Mauritius proposed to engage in marine geoengineering activities to meet their commitments. See Anja Chalmin, "Geoengineering Projects in Africa Intensify Along with Oil and Gas Expansion", *supra* note 784.

[789] Ibid.

[790] Republic of Rwanda, "Updated Nationally Determined Contribution" (May 2020). Available at: https://unfccc.int/sites/default/files/NDC/2022-06/Rwanda_Updated_NDC_May_2020.pdf at 21.

[791] Cabo Verde, "2020 Update to the First Nationally Determined Contribution (NDC)", (February 2020). Available at: https://www.geoengineeringmonitor.org/2022/05/quarterly-review-i-part-3-marine-geoengineering-ongoing-and-planned-open-ocean-trials-and-recent-developments-in-research/?print=pdf at 30.

utilize the energy potential of tides, current, waves, and wind.[792] Thus, the stakeholders on the continent are compelled to ensure that these geoengineering mitigation activities do not pose a danger to the marine environment.

In West Africa, researchers have commissioned several geoengineering projects, particularly investigating the impacts of Solar Radiation Management (SRM) on the continent. In 2019, they commenced the DECIMALS research project in Benin.[793] The research project was organized by the Solar Radiation Management Government Initiative (SRMGI) as one of eight SRM research projects to examine the impacts of SRM on the continent.[794] In 2023, another research project was commissioned in Benin to explore the impacts of SRM on chlorophyll, plankton, and nutrient cycles along the coastal countries of the Gulf of Guinea.[795] Furthermore, in Ghana, the research project commissioned examines the impacts of SRM could have on regional temperature, humidity, and rainfall in a warming climate.[796] In Mali, the research project models the impacts of SRM on droughts from meteorological, agricultural, and hydrological perspectives.[797] In Nigeria, the research project focuses on how different crop

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[792] Republic of Mauritius, "Update of the Nationally Determined Contribution of the Republic of Mauritius" (01 October 2021). Available at: https://unfccc.int/sites/default/files/NDC/2022-06/Final%20Updated%20NDC%20for%20the%20Republic%20of%20Mauritius%2001%20October%202021.docx at 8.
[793] The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "SRM Engagement Workshop in Cotonou, Benin" (2019), available at: https://www.degrees.ngo/events/benin-august-2019/.
[794] Ibid.
[795] The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Marin Biogeochemistry and Sea Level in the Gulf of Guinea" (2023), available at: https://www.degrees.ngo/dmf/the-projects/benin-2023/.
[796] The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Exploring Changes to the Harmattan Windy Season and Precipitation in Southern West Africa" (2023), available at: https://www.degrees.ngo/dmf/the-projects/ghana-2023/.
[797] The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Exploring Whether SRM Could Offset Droughts in West Africa" (2023), available at: https://www.degrees.ngo/dmf/the-projects/mali-2023/.

types- such as cereals, legumes, horticulture, and root and tubers - will react to different temperature scenarios, both with and without the use of SRM.[798]

In addition to the research activities, authorities have earmarked the maritime jurisdiction of Cabo Verde as a location for marine geoengineering projects. Cabo Verde has become a destination for an upcoming artificial upwelling trial in spring 2023,[799] thus prompting the need to institute measures to prevent or reduce the impacts of experiments on the marine environment. This experiment is going to be conducted by the UK-based Seafields Solutions Limited in collaboration with Cabonwave,[800] and it aims to employ two main marine geoengineering techniques: artificial upwelling and storage of carbon in the ocean by the cultivation of macroalgal techniques.[801] The project aims to cultivate the seaweed Sargassum in the open sea, compress the harvested seaweed into bales and dunk it into the deep sea.[802]

These developments in the sub-region imply that all stakeholders must brace themselves to develop, monitor and enhance measures to guarantee a practical governance framework for marine geoengineering activities. Following from above, the following parts trace and examine the governance framework of marine geoengineering in West Africa.

[798] The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Assessing the Effects of SRM on Crops in West Africa" (2023), available at: https://www.degrees.ngo/dmf/the-projects/nigeria-2023/.
[799] Anja Chalmin, "Geoengineering- Ongoing and Planned Open-Ocean Trials and Recent Developments in Research" (6 May 2022), available at: https://www.geoengineeringmonitor.org/2022/05/quarterly-review-i-part-3-marine-geoengineering-ongoing-and-planned-open-ocean-trials-and-recent-developments-in-research/?print=pdf. [Anja Chalmin, "Geoengineering- Ongoing and Planned Open-Ocean Trials and Recent Developments in Research"].
[800] Ibid.
[801] Ibid.
[802] Ibid.

5.3 Tracing Marine Geoengineering Governance in West Africa

The ocean remains an essential source of livelihood for many Coastal States in West Africa.[803] According to UNEP, the ecosystem within which the Abidjan Convention operates supports rich fisheries, tourism, industry, and busy ports.[804] Coastal communities in West Africa rely heavily on the ocean for their sustenance. Nevertheless, the ocean remains threatened by climate change, improper use of resources, extensive pollution, and other externalities.[805] Researchers predict climate change will likely increase coastal erosion and flooding in the region.[806]

The Convention for Cooperation in the Protection, Management, and Development of the Marine and Coastal Environment of the Atlantic Coast of the West and Central Africa Region (Abidjan Convention) is the leading regional instrument that governs the maritime jurisdictions of West African States. Like the Barcelona Convention, the Abidjan Convention is a framework convention administered by the UNEP.[807] The Abidjan Convention is a framework treaty that covers the marine environment, coastal zones, and related inland waters falling within the jurisdiction of West African and Central African States.[808] The Convention also covers the marine environment, coastal zones, and related inland waters spanning from Mauritania to the Western Coast of South Africa.[809]

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[803] United Nations Environment Programme, "West and Central Africa", available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/west-and. [UNEP, "West and Central Africa"].
[804] Ibid.
[805] Ibid.
[806] Ibid.
[807] Abidjan Convention, Art. 16.
[808] Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region and Protocol, 23 March 1981, ILM Vol. 20, p. 746-76 Art.1. [Abidjan Convention].
[809] UNEP, "West and Central Africa", *supra* note 801. South Africa acceded to the Convention in 2000 and ratified it in 2002. The Secretariat established by the Convention received the instruments of ratification of Namibia and Angola in 2017. In 2019, Cabo Verde acceded to the Convention as well.

The Abidjan Convention does not directly address marine geoengineering. The Convention entered into force long before geoengineering became a hot topic in climate change discourse.[810] Nevertheless, the Convention contains relevant provisions, particularly the dumping regime,[811] that govern marine geoengineering activities in West Africa.

The Abidjan Convention imposes general obligations on all Contracting Parties to protect and preserve the marine environment in West and Central Africa. According to article 4 of the Abidjan Convention, all Parties must take appropriate measures to prevent, reduce, combat, and control pollution of the region of the ocean which is governed by the C0nvention.[812] The obligation to prevent, reduce, combat, and control pollution applies to the obligation to exploit natural resources in a sound environmental manner.[813] Furthermore, Contracting Parties to the Convention are required to establish and harmonize national laws and regulations for the effective discharge of their obligations under the Convention.[814] The obligation to protect and preserve the marine environment includes an obligation on all Contracting Parties to avoid transboundary pollution in their efforts to prevent, reduce, combat, and control pollution or promote environmental management.[815] Thus, in this context, the Abidjan Convention imposes an obligation on West African States to prevent, reduce, combat, and control pollution arising out of marine geoengineering activities.

The Abidjan Convention urges Contracting Parties to cooperate among themselves and with competent international, regional, and subregional organizations to prevent, reduce, combat,

[810] The Convention came into force in 1984, before geoengineering became a potential climate change mitigation option.
[811] Abidjan Convention, Art. 6.
[812] Abidjan Convention, Art. 4.
[813] Abidjan Convention, Art. 4.
[814] Abidjan Convention, Art. 4.
[815] Abidjan Convention, Art. 4.

and control pollution.[816] The Abidjan Convention mandates all States to cooperate in the formulation and adoption of Protocols prescribing agreed measures, procedures, and standards to protect and preserve the marine environment or promote environmental management in accordance with the objectives of the convention.[817] It further urges States to cooperate with competent international, regional, and subregional organizations to establish and adopt recommended practices, procedures, and measures which will protect and preserve the marine environment in conformity with the Abidjan Convention. The obligation to cooperate in this context also applies to scientific research.[818] The Contracting Parties have yet to negotiate a Protocol or a regional instrument to regulate marine geoengineering activities in the region. Over the years, several partnerships have been entered into between UNEP, the West African government, donors, and non-governmental organizations to address environmental issues.[819] However, there is yet to be a documented collaboration by these players on marine geoengineering in the sub-region.

Furthermore, the dumping regime of the Abidjan Convention is extensive. It covers activities or substances deemed as pollution recognized by other international instruments.[820]

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[816] Abidjan Convention, Art. 4; Ghana, Nigeria, and Sierra Leon are the West African countries parties to the London Protocol as of April 2022. Chad, Cote D'Ivoire, Gabon, and Nigeria are parties to the London Convention. Thus, the resolutions adopted by the Contracting Parties to the London Convention and London Protocol to regulate marine geoengineering activities do not bind most West African States. Nevertheless, customary international law obligates all States to protect and preserve the ocean and its ecosystem. For the list of countries that are parties to the London Convention. See Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, 29 December 1972, 1046 UNTS 120 (entered into force 23 June 1977). Available at: https://treaties.un.org/pages/showDetails.aspx?objid=08000002800fdd18 ; for the list of parties to the London Protocol as of April 2022. See International Maritime Organization, "Maps of Parties to the London Convention/Protocol". Available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/LC_LP/Map%20of%20Parties%202022.pdf.

[817] Abidjan Convention, Art. 4.

[818] Abidjan Convention, Art. 14. The Abidjan Convention mandates Contracting Parties to exchange data and information, as well as cooperate in the field of scientific research, monitoring, and assessment of pollution with the assistance of competent international and regional organizations.

[819] UNEP, "West and Central Africa", *supra* note 801.

[820] Abidjan Convention, Art. 6.

Article 6 of the Abidjan Convention urges Contracting States to take appropriate measures to prevent, reduce, combat, and control pollution by dumping from ships and aircraft.[821] It incorporates the application of internationally recognized rules and standards on ocean dumping.[822] Unlike the other regional agreements, the Abidjan Convention does not define dumping.[823] However, based on article 6 the rules and standards on ocean dumping as stipulated by the London Convention apply in this context. It is instructive to state that most West African countries are neither signatories to the London Convention nor the London Protocol. Four out of nineteen countries in West Africa are parties to the London Convention.[824] Only Ghana, Nigeria, and Sierra Leone are parties to the Protocol.[825] Thus, the standards in the London Convention and Protocol on dumping applies to non-party (London Convention and Protocol) States by virtue of article 6.

The Abidjan Convention does not expressly mention marine geoengineering. Nevertheless, the duty to protect and preserve the marine environment stipulated by the Convention extends to marine geoengineering activities involving seabed and subsoil exploration. The Convention requires all Contracting Parties to take appropriate measures to prevent, reduce, combat, and control pollution involving activities relating to the exploration and exploitation of the seabed and its subsoil within the jurisdiction of the Contracting Party and

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[821] Abidjan Convention, Art. 6.
[822] Abidjan Convention, Art. 6.
[823] The definition of dumping by the London Convention could be adopted to make up for this lacuna. The Abidjan Convention incorporates international rules and standards on dumping. Thus, the London Convention, which sets international rules and standards to prevent, reduce, and control pollution by dumping, applies. See Karen N. Scott, "Regulating Ocean Fertilization under International Law: The Risks", *supra* note 335.
[824] In West Africa, Cote d'Ivoire, Equatorial Guinea, Nigeria, and Sierra Leone are parties to the London Convention. See Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, 29 December 1972, 1046 UNTS 120 (entered into force 23 June 1977). Available at: https://treaties.un.org/pages/showDetails.aspx?objid=08000002800fdd18.
[825] For the list of parties to the London Protocol as of April 2022. See International Maritime Organization, "Maps of Parties to the London Convention/Protocol". Available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/LC_LP/Map%20of%20Parties%202022.pdf.

from artificial islands, installations, and structures under their jurisdiction.[826] Thus, all marine geoengineering activities that involve the exploration and exploitation of the seabed and its subsoil are expected to comply with this provision.[827]

Furthermore, the Abidjan Convention establishes an obligation on all Parties to develop and include an environmental impact assessment (IEA) in any activity carried out within their maritime jurisdictions.[828] The Convention urges all Contracting Parties to develop an EIA framework as part of environmental management policy to help plan their development projects. West African States must conduct an EIA of the potential impacts of projects in the ocean that may cause substantial pollution.[829] Marine Geoengineering activities can cause substantial marine pollution.[830] Hence, an environmental impact assessment must be issued for all exploration and exploitation of the seabed to sequester carbon.

Furthermore, the scope of the Protocol to the Abidjan Convention Concerning Cooperation in the Protection and Development of Marine and Coastal Environment from Land-Based Sources and Activities in the Western, Central, and Southern African Region (LBSA Protocol)[831] applies to some marine geoengineering activities. To begin with, the objective of this Protocol is to protect and sustain the marine and coastal environment described in the Abidjan Convention through the prevention, reduction, mitigation, and control of pollution from land-based sources and activities on the territories of Contracting States or emanating from any

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[826] Abidjan Convention, Art. 8.
[827] Presently, all conceivable geoengineering activities involve the exploration or exploitation of the seabed to be able to sequester carbon.
[828] Abidjan Convention, Art. 13.
[829] Abidjan Convention, Art. 13.
[830] See Chapter Two for an extensive discussion on the environmental pollution activities caused by marine geoengineering.
[831] Protocol to the Abidjan Convention Concerning Cooperation in the Protection and Development of Marine and Coastal Environment from Land-Based Sources and Activities in the Western, Central, and Southern African Region (adopted on 22 June 2012, not yet in force). [LBSA Protocol].

other land-based sources.[832] The Protocol applies to sources and activities within the territories of Contracting States that may affect the marine and coastal environment. Thus, marine geoengineering techniques such as enhancing ocean alkalinization, which involves accelerating the weathering of limestone, spreading olivine within coastal and shelf environments, or amending cropland soils with crushed reactive silicates[833] and which may affect the marine and coastal environment is fall within the scope of the Protocol. Also, the large-scale deployment of techniques like OTEC in West Africa could result in a change in the ecosystem, thus making the Protocol applicable to such activities.[834]

The LBSA Protocol imposes general obligations on all Contracting Parties relevant to marine geoengineering governance in the region. The Protocol urges States to take appropriate measures to prevent, reduce, mitigate, and control pollution and degradation of the marine and coastal environment from land-based sources and activities.[835] Consequently, ocean alkalinization and OTEC activities which are likely to adversely affect the marine and coastal environment must be avoided. Furthermore, the LBSA Protocol imposes an obligation on States to cooperate in the formulation and adoption of measures and international environmental standards which are crucial to prevent, reduce, mitigate, and control pollution from land-based sources and activities.[836] Presently, there has not been any negotiation in West Africa to formulate and adopt measures, procedures, practices, and standards for marine geoengineering. Nonetheless, any future negotiation could consider the generic Assessment Framework for marine geoengineering in the London Protocol. In the formulation of action plans, programs, and

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[832] LBSA Protocol, Art. 1. The Protocol defines "land-based sources and activities" to be activities, sources and factors directly or indirectly causing or contributing to the pollution of the marine and coastal environment from the landward side as opposed to activities, sources, and factors from the seaward side.
[833] GESAMP, *supra* note 53 at 65 and 66.
[834] GESAMP *supra* note 53 at 76.
[835] LBSA Protocol, Art. 5(1).
[836] LBSA Protocol, Art. 5(1).

measures on marine geoengineering in consonance with the Protocol, authorities must give due regard to issues of eutrophication.[837]

The Abidjan Convention and the LBSA Protocol govern marine geoengineering activities using general provisions and obligations. Unlike the OSPAR Convention, which caters to carbon sequestration activities in the North-East Atlantic, the Abidjan Convention (which adopts a similar approach as the Barcelona Convention and the Helsinki Convention) does not have provisions governing carbon sequestration activities. Furthermore, like the Mediterranean Sea region, the West African Region is governed by a framework treaty administered by UNEP. It has neither adopted a Protocol to regulate carbon sequestration activities nor amended the operative treaty to govern it. However, unlike the Baltic Sea Region, the following parts of this Chapter will show that there is no directive or guideline on carbon storage operating within the West African Region to govern marine geoengineering activities.

5.4 The African Union's Climate Change Structures and Their Contribution to Marine Geoengineering Governance

The African Union (AU) is a continental body established in 1963 as the Organization of African Unity.[838] It consists of fifty-five (55) member states and was officially launched as the AU in 2002.[839] The aims of the AU include the promotion of sustainable development, promoting research in all fields, and encouraging international cooperation among others.[840]

Over the years, the AU has spearheaded climate change issues on the continent through its established structures. The AU has three climate change negotiating structures for climate

[837] LBSA Protocol, Annex I(4) and (6).
[838] African Union, "About the African Union". Available at: https://au.int/en/overview.
[839] Ibid.
[840] Ibid.

change, comprising the African Group of Negotiators (AGN), the African Ministerial Conference on the Environment (AMCEN), and the Committee of African Heads of State and the Government on Climate Change (CAHOSCC).[841] AGN serves an avenue for the Member States to develop and maintain a unified African voice in climate negotiation.[842] AMCEN was established in 1985, and its mandate includes the responsibility to promote awareness and consensus on global and regional environmental issues.[843] CAHOSCC collaborates with the two other structure -AGN and AMCEN – to advance a unified African position on climate change at the international stage.[844]

Besides the contribution of the AU climate change structures, there has not been any significant regional development of a governance strategy for marine geoengineering activities on the continent.[845] As of June 2023, none of the resolutions passed by the organs and structures of the AU on climate change directly consider issues surrounding marine geoengineering activities.[846] Moreso, it is often the case that resolutions passed by the AU on climate change and its impacts are conveyed in hortatory language.[847] For instance, AMCEN at its Fifth Session passed a resolution re-echoing its functions to include monitoring the implementation of regional and global conventions and agreements relevant to Africa, especially the Bamako Convention on

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841 AU Climate and Resilient Development Strategy and Action Plan, *supra* note 14 at 31.
842 African Group of Negotiators on Climate Change, "Structure and Membership of the AGN". Available at: https://africangroupofnegotiators.org/about-the-agn/.
843 United Nations Environment Programme, "About AMCEN". Available at: https://www.unep.org/regions/africa/african-ministerial-conference-environment/about-amcen.
844 African Union, "Meeting of the Committee of African Heads of State and Government on Climate Change (CAHOSCC)". Available at: https://au.int/en/newsevents/20220206/meeting-committee-african-heads-state-and-government-climate-change-cahoscc.
845 For the resolutions passed by the Executive Council or the Assembly of the African Union, see, African Union, "Decisions & Declarations". Available at: https://au.int/en/decisions/assembly%E2%80%8B.
846 This could partly be due to the absence of significant developments in marine geoengineering activities on the continent.
847 The African Ministerial Conference on the Environment (AMCEN) is yet to pass a resolution stating its position on geoengineering activities on the continent. For resolutions and decisions passed by AMCEN over the years. See United Nations Environment Programme, "AMCEN Past Sessions". Available at: https://www.unep.org/regions/africa/african-ministerial-conference-environment/amcen-past-sessions.

Hazardous Waste,[848] CBD, and UNFCCC regimes.[849] The situation is no different in the case of AGN which is yet to make a submission on the continent's position on the role and regulation of marine geoengineering activities in Africa at the UNFCCC.[850]

The absence of binding decisions, rules, or standards by these structures leaves West African countries in no better position to regulate marine geoengineering activities. As earlier indicated, many West African States are not parties to the London Convention and London Protocol – an international legal regime that has developed and adopted many decisions on marine geoengineering activities. The absence of a binding resolution on marine geoengineering leaves West African countries with the leeway to govern such activities under broad and implied obligations stipulated in other multilateral agreements such as UNCLOS and in accordance with international customary law principles.

5.5 The Climate and Resilient Development Strategy and Action Plan and Marine Geoengineering Governance in West Africa

The African Union acknowledges the role of carbon capture and storage technologies in addressing climate change. In 2022, the AU adopted the African Union Climate and Resilient

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[848] Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, 30 January 1991, 2101 UNTS 177 (22 April 1998).

[849] The African Ministerial Conference on the Environment, *Decision Adopted by Conference at its Fifth Session* UNEP/AMCEN.5/3. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/20559/Amcen_5_decisions.pdf?sequence=1&isAllowed=y. Similarly at its Eight Session, AMCEN decided to work towards formulating common positions on the implementation of the UNFCCC's Bueno Aires Plan of Action and the development of mechanisms adopted by the Plan of Action including the Clean Development Mechanism, technology transfer, and capacity building. See The African Ministerial Conference on the Environment, *Decision Adopted by the AMCEN at its Eight Session*, UNEP/AMCEN/8/5 Annex II. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/20583/Amcen_8_decisions.pdf?sequence=1&isAllowed=y.

[850] The African Group of Negotiators (AGN) are yet to express their position on marine geoengineering to the UNFCCC. For the statements and submissions made by the AGN to the UNFCCC, see, African Groups of Negotiators on Climate change, "AGN Submissions and Statements to the UNFCCC". Available at: https://africangroupofnegotiators.org/document-library/agn-submissions-to-the-unfccc/.

Development Strategy and Action Plan ("Strategy and Action Plan")[851] which highlighted the potential of carbon capture and storage technologies such as direct air capture and storage in Africa.[852] According to the Strategy and Action Plan, the abundance of renewable energy on the continent serves as an opportunity to explore the potential of carbon capture and storage technologies on the continent through the support of developed nations.[853] The document underscores the importance of ecosystem approaches and ecosystem adaptation in enhancing the sequestration of carbon and the adaptation of society in response to climate change.[854] Some of the approaches listed in the document include the reforestation of hills slopes, revegetation of riverine areas, and wetland restoration to act as carbon sinks.[855] The document also identifies land-based ecosystem approach as a priority for the continent and an avenue to improve soil carbon storage.[856]

The Strategy and Action Plan identifies the need to develop a governance framework for carbon dioxide removal technologies, solar radiation management technologies, and synthetic biology and genetic engineering approaches in response to climate change.[857] The AU reiterates the need to stick to a primary mitigation and adaptation strategy because it remains the best option to address climate change.[858] However, it notes that many governments, universities, and private institutions are proactively engaged in research and developing novel approaches including developing geoengineering techniques to address climate change.[859] The AU indicates

[851] AU Climate and Resilient Development Strategy and Action Plan, *supra* note 14.
[852] Ibid., 44. Whereas AU recognizes the potential of carbon capture and storage technologies to its member States, one of its Member States - Rwanda – deems this technology as a "highly unfeasible option". See the Republic of Rwanda, "Updated Nationally Determined Contribution", *supra* note 788.
[853] AU Climate and Resilient Development Strategy and Action Plan, *supra* note 14 at 44.
[854] Ibid., 25.
[855] Ibid.
[856] Ibid., 40.
[857] Ibid., 28.
[858] Ibid.
[859] Ibid.

that these novel approaches raise legal, ethical, and social considerations which call for the development of a governance framework capable of regulating these activities within the African context. [860] It is often the case that the call for the development of a governance framework for marine geoengineering activities at the global or regional level kickstarts with the passage of a binding resolution.[861] In this context, the continent is yet to pass any binding resolution either under the Abidjan Convention or using the climate change structures of the AU. Furthermore, even though the Strategic Document identifies issues inherent in the governance of geoengineering techniques, it does not have the effect of law, thus leaving the issue of geoengineering governance at the regional level unabated.

Establishing a robust governance framework for marine geoengineering in Africa will require contributions from all stakeholders, including technocrats, policymakers, governments, and non-governmental organizations. According to AU, geoengineering governance at the regional level poses challenges. Thus it urged all stakeholders to increase their attention on the impacts of these technologies on Africa.[862] It beseeched African policymakers to consider issues like access to and control over geoengineering technologies, access to finance, questions of liability and accountability, development of insurance mechanisms, questions of private versus public control or use, access to and control over data, and juxtapose the risk in the usage of the technology vis-à-vis the risks inherent in climate change.[863]

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[860] Ibid.
[861] See chapters three and four for instances where binding decisions regulate marine geoengineering activities.
[862] Ibid.
[863] Ibid; the African Union, at its Thirty-Sixth Ordinary Session, held between 18-19 February 2023, took notice of the implementation of the African Union Climate Change and Resilient Development Strategy and Action Plan (2022-2023) and urged the African Union Commission to enhance the capacity of member states to access climate finance to implement multiple programs. See African Union, *Decision on the Report of the Coordinator of the Committee of African Heads of State and Government on Climate Change (CAHOSCC)* Assembly/AU/Dec.855 (XXXVI). Available at: https://au.int/sites/default/files/decisions/42725-Assembly_AU_Dec_839_-_865_XXXVI_E.pdf at para. 28.

The AU urged African governments, research institutes, and civil society organizations to make relevant inputs in research, development, and regulation of geoengineering at the international level.[864] Critical to AU's call for geoengineering governance is the concern that the impacts of these techniques are global in character, therefore there is the need for the continent to play a significant role in the early research, development, and regulation of geoengineering activities.[865] In AU's estimation the horse has not left the barn and a timeous intervention by these groups could present opportunities to conduct, shape, and direct research which advances the needs, concerns, and contexts of the African Continent.[866] Other opportunities in this regard will include shaping technology transfer, as well as improving innovation in African research institutes.[867]

Furthermore, the African Union Climate and Resilient Development Strategy and Action Plan outlines the impacts of climate change on the ocean and the potential opportunities that the ocean presents the continent towards addressing climate change.[868] The document highlights the need to address climate change to position the continent to meet its commitment to the Sustainable Development Goal (SGD), especially SDG14 (Life below water)[869] and its Agenda 2063[870].[871] It observed that the ocean absorbs substantial heatwaves generated by greenhouse

[864] Ibid.
[865] Ibid.
[866] Ibid.
[867] Ibid.
[868] Ibid., 25.
[869] United Nations, "Goal 14: Conserve and Sustainably Use the Oceans, Seas, and Marine Resources for Sustainable Development", available at: https://sdgs.un.org/goals/goal14.
[870] African Union, "Agenda 2063: The Africa We Want" (September 2015). Available at: https://au.int/sites/default/files/documents/36204-doc-agenda2063_popular_version_en.pdf. Agenda 2063 signifies the aspirations and determination of the African people. The Heads of State and Government of the Africa Union reiterated their commitment to fulfill these aspirations. In terms of climate change, the people of Africa observed that Africa contributes less than 5% of global carbon emission, yet it bears the brunt of the impact of climate change. It plans to prioritize adaptation to ensure the implementation of actions for the survival of the most populations. Furthermore, it commits to participate in global efforts for climate change mitigation that supports the sustainable development of the continent. See Aspiration 1 of Agenda 2063.
[871] AU Climate and Resilient Development Strategy and Action Plan, *supra* note 14 at 25.

gases, as well as sequesters atmospheric carbon dioxide. Hence it plays a significant role in addressing climate change and its impacts.[872] Moreso, it lists some of the primary impacts of climate change on the ocean, including the changes in oceanic temperature, ocean acidification, and deoxygenation,[873] and indicates that these impacts have secondary effects on the environment, thus causing sea-level rise, increased storm intensity and the changes in the distribution, diversity, and abundance of marine species.[874] The impacts of climate change raise economic and food security concerns for the continent and humanity as a whole.[875]

In the context of carbon sequestration, the AU urged its members to enhance the capabilities of the ocean to sequester carbon dioxide.[876] It notes that measures such as the expansion of mangroves and ocean alkalinization could enhance the capability of the ocean to sequester more carbon dioxide,[877] create a livelihood for coastal communities, and serve as an avenue to boost financial flows because of mitigation efforts.[878]

Based on the potential of the ocean to sequester carbon, the AU calls for an integrated approach to governance approaches and mechanisms. It urges member States to build on significant investment in co-management, ecosystem-based governance approaches, integrated coastal zone management, and emerging practices in marine spatial planning.[879] In its view, a regional governance framework for climate change will be essential in addressing the

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872 Ibid.
873 Ibid.
874 Ibid.
875 Ibid.
876 Ibid.
877 Ibid. The African Union needs to indicate which of the ocean alkalinization processes could enhance the sequestration coefficient of the ocean, as well as boost economic growth. Ocean alkalinization could be carried out by adding lime directly to the ocean, adding carbonate minerals, accelerating the weathering of limestone, dissolution of olivine in the ocean, by electrochemical enhancement of carbonate and silicate mineral weathering, spreading olivine within coastal and shelf environments, by amending cropland soils with crushed reactive silicates, or by brine thermal decomposition of desalination reject brine. For a discussion on how to carry out ocean alkalinization, see GESAMP, *supra* note 53 at 65 and 66.
878 Ibid.
879 Ibid.

phenomena.[880] It urged on member States to see the need to 'leverage existing regional institutions and programs to support joint research, sharing of data and good practice, and joint program implementation in strengthening the climate resilience of Africa's blue economy."[881]

The Strategy Document and Action Plan remains the most significant step taken on marine geoengineering on the continent so far. The African Union Climate and Resilient Development Strategy and Action Plan does not impose any legal obligation on Member States or create rights on subjects of international law. It does not have the same effect as a binding international instrument or resolution; at best, it serves as soft law.[882] Nevertheless, the principle of good faith it establishes creates an expectation on the Member States to implement the strategies and action plans at the national and regional level.

5.6 Marine Geoengineering Governance in West Africa: The Role of the Economic Community of West African States (ECOWAS)

5.6.1 The Role of the ECOWAS Treaty to Marine Geoengineering Governance

The Economic Community of West African States (ECOWAS) was established in 1975 by the coming into force of the ECOWAS Treaty.[883] ECOWAS aims to promote cooperation and integration, resulting in the establishment of an economic union in West Africa to improve the standard of living of citizens of member countries, and to maintain and enhance economic stability, promote relations among its members and contribute to the progress and development

[880] Ibid.
[881] Ibid.
[882] Alan Boyle & Catherine Redgwell, *supra* note 474.
[883] Articles of Association for the Establishment of an Economic Community of West Africa, 4 May 1967, 595 UNTS 287 (entered into force on 4 May 1967), Art. 1. [ECOWAS Treaty].

of the African continent.[884] Its objectives include the harmonization and coordination of policies to protect the environment.[885]

The ECOWAS Treaty contains relevant provisions that obligate Member States to protect and preserve the environment. The treaty imposes an obligation on Member States to protect, preserve, and enhance the environment of the region and cooperate amongst themselves in the event of natural disaster.[886] In this regard, it urges member States to adopt policies, strategies, and programs at the national and regional levels to protect, preserve and enhance the environment.[887] It also urges member States to establish appropriate institutions to protect, preserve, and enhance the environment.[888] The duty to protect and preserve the environment has attained the status of customary international law,[889] thereby imposing an obligation on all West African States to ensure that all marine geoengineering experiments carried within their maritime jurisdiction do not pollute and cause harm to the marine environment.

Furthermore, the treaty prohibits the dumping of hazardous and toxic wastes in the region[890] and urges member States to adopt a regional dump watch to prevent the importation, transiting, dumping, and burying of these substances.[891] However, the treaty neither defines "hazardous and toxic wastes" nor "dumping". However, unlike the Abidjan Convention, the ECOWAS Treaty neither incorporates internationally recognized rules and standards regulating the control of pollution by dumping nor does the poor rate of adoption of the London Convention and London Protocol by the West African States likely to enhance the implementation of the

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[884] ECOWAS Treaty, Art. 3(1).
[885] ECOWAS Treaty, Art. 3(2)(b).
[886] ECOWAS Treaty, Art. 29(1).
[887] ECOWAS Treaty, Art. 29(2).
[888] ECOWAS Treaty, Art. 29(2).
[889] Moira L. McConnell & Edgar Gold, *supra* note 361; Jonathan. L. Hafetz, *supra* note 301 at 597; Martin H. Belsk, *supra* note 301.
[890] ECOWAS Treaty Art. 30(1).
[891] ECOWAS Treaty, Art. 30(2).

dumping regime of the treaty. In effect, the governance of marine geoengineering activities under the dumping regime of the ECOWAS Treaty may not achieve the intended results.

5.6.2 Examining the Role of ECOWAS Policies in Governing Marine Geoengineering Activities

The policies implemented by ECOWAS are crucial to protecting and preserving the environment. ECOWAS is a regional economic integration organization that aims to achieve regional integration among West African Countries.[892] In 2008, it developed the ECOWAS Environment Policy to reverse environmental degradation and the depletion of natural resources, improve the quality of the living environment, and conserve biological diversity.[893] At its thirty-fifth ordinary session, Member States adopted the Supplementary Act relating to the ECOWAS Environmental Policy which established the scope of the Environmental Policy to include the preservation of the ecosystem and biodiversity, as well as the prevention and management of technological risks, the climate, pollutions, and other environmental risks.[894] Moreover, it has adopted numerous policies and strategic documents to address the impacts of climate change on the subregion.[895]

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[892] Economic Community of West African States (ECOWAS), "ECOWAS Regional Climate Strategy (RCS) and Action Plan (2022-2030"). Available at: http://www.climatestrategy.ecowas.int/images/documentation/ECOWAS%20Regional%20Climate%20Strategy_adopted%20june%202022.pdf.
at 25. [ECOWAS Regional Climate Strategy].

[893] Economic Community of West African States (ECOWAS), ECOWAS Environment Policy (Abuja, Nigeria: Environment Directorate. 2008). The policy document does not cover climate change. It covers it in a broad context regarding environmental governance and capacity building.

[894] Economic Community of West African States (ECOWAS), *Supplementary Act A/SA.4/12/08 Relating to the ECOWAS Environmental Policy*. Available at https://ecowap.ecowas.int/media/ecowap/related-policy/ECOWEP_-_ECOWAS_Environmental_Policy_EN.pdf Art. 3.

[895] Some examples of ECOWAS climate interventions in the subregion include the following: the ECOWAS Renewable Energy Policy in 2015. see, Economic Community of West African States (ECOWAS), "ECOWAS Renewable Energy Policy (2015)". Available at: http://www.ecreee.org/sites/default/files/documents/ecowas_renewable_energy_policy.pdf; the Intervention framework for climate-smart agriculture in the Sahel and West Africa in 2015. See, Economic Community of West African States (ECOWAS), "Intervention Framework for the Development of Climate-Smart Agriculture under the West Africa Regional Agricultural Policy (ECOWAP/CAADP) Implementation Process" (15-18 June 2015).

In 2022, the ECOWAS adopted its regional climate strategy in Ghana, which contains mitigation and adaptation measures to address climate change.[896] The ECOWAS earmarked five (5) sectors that it considers areas of priority for climate mitigation measures. These sectors are agriculture, forestry and other land uses, energy, transport and mobility, industrial processes and product uses, and waste.[897]

Besides these priority areas, the strategic document discusses atmospheric carbon sequestration measures. However, these carbon sequestration techniques are limited to the sequestration of carbon in the soil through agriculture.[898] It remains unclear whether the sequestration of atmospheric carbon dioxide through agriculture applies to the cultivation of macroalgal as a sequestration technique.[899]

The legal and policy frameworks of ECOWAS need to adequately institute a mechanism for governing marine geoengineering activities. There needs to be more clarity on the application of the dumping regime of the ECOWAS Treaty to marine geoengineering activities.

Available at: http://www.hubrural.org/IMG/pdf/ecowas_ecowap_intervention_framework_for_csa_june_2015_final.pdf; the Strategic framework for the 2025 horizon of the ECOWAS Agricultural Policy in 2017. See, Economic Community of West African States (ECOWAS), "Strategic framework for the 2025 horizon of the ECOWAS Agricultural Policy in 2017 (see, Economic Community of West African States (ECOWAS), *2025 Strategic Policy Framework* (November 2017). Available at: https://faolex.fao.org/docs/pdf/eco191485.pdf; Economic Community of West African States (ECOWAS), "ECOWAS Disaster Risk Reduction Gender Strategy and Action Plan 2020-2030*"* (28 April 2020)". Available at: https://www.gfdrr.org/sites/default/files/publication/ECOWAS%20GSAP_EN_Final.pdf.

[896] ECOWAS Regional Climate Strategy, supra note 856; Economic Community of West African States (ECOWAS), "Eighty-Sixth Ordinary Session of the ECOWAS Council of Ministers to hold in Accra" (15 June 2021). Available at: https://ecowas.int/eighty-sixth-ordinary-session-of-the-ecowas-council-of-ministers-to-hold-in-accra/#:~:text=The%20Eighty%2DSixth%20Ordinary%20Session,Movenpick%20Hotel%20in%20Accra%2C%20Ghana.

[897] ECOWAS Regional Climate Strategy, *supra* note 856 at 22. The absence of the ocean is surprising, considering the African Union acknowledges the crucial role that the ocean could play in addressing climate change and its impacts on the continent. See African Union, "Agenda 2063: The Africa We Want" *supra* note 868.

[898] ECOWAS Regional Climate Strategy, supra note 856 at 140. The document envisages the significant contribution of agriculture to the sequestration of atmospheric carbon. It also notes that initiatives are being implemented (financed by the European Union) at the regional level to improve the evaluation of the carbon footprint of Sahelian (agro) sylvo-pastoral ecosystems.

[899] The marine environment is not featured in the list of priorities. Therefore, marine geoengineering must be considered outside the strategic document.

In the same vein, the policies adopted and implemented by ECOWAS do not focus on addressing marine geoengineering governance.

CHAPTER SIX: CONCLUSION

The global and regional governance regimes on marine geoengineering are gradually taking shape. The inroads made by the Contracting Parties to the CBD and London Convention and London Protocol are considerable progress in ensuring a robust regulation of marine geoengineering activities. Likewise, the contribution of other multilateral environmental agreements in developing a robust governance framework for these technologies is relevant in this regard.

At the regional level, the regulation of marine geoengineering activities has not been uniform. The Baltic, Mediterranean, and North-East Atlantic Sea regions adopt varied approaches to governing carbon sequestration activities in the ocean. The diversity reflected in these governance regimes at the regional level presents West Africa with a wide array of options to establish a robust governance framework for marine geoengineering tailored to suit the subregion.

Based on the preceding chapters, the following parts analyze the governance approaches in West Africa and other regions. The analysis aims to identify the extent to which West Africa's governance regime departs from the Baltic, Mediterranean, and North-East Atlantic Regions.

6.1 Analysis of Marine Geoengineering Governance in the West African Region and Other UNEP Regional Seas Programmes.

The following parts analyze the West African regional sea program vis-à-vis the Baltic Sea, Mediterranean Sea, and the North-East Atlantic Region on marine geoengineering governance. The analysis is conducted based on three indicators:

- the extent of participation in international multilateral environmental agreements (discussed in Chapter Three) in the region,
- the mechanisms instituted by regional environmental agreements to govern these activities, and
- the use of other regional sources of law instruments, including soft law to govern marine geoengineering.

6.1.1 The Extent of Participation in International Multilateral Agreements

The international multilateral agreements to be considered in this part are the UNCLOS, CBD, London Convention and London Protocol, and the UNFCCC regime. Chapter Three discusses these agreements based on marine geoengineering governance at the global level.

All the countries in the Baltic, Mediterranean, North-East Atlantic, and West African region are parties to the UNCLOS, thus making the obligations established under the Convention apply in all these regions.[900] All the West African States are signatories to UNCLOS and have also ratified the instrument in their respective jurisdictions.[901] In the Baltic Sea region, all the countries have either signed and ratified the Convention or have acceded to it.[902] Countries in the North-East Atlantic region are all parties to UNCLOS.[903] The countries constituting the Mediterranean Sea Region are parties to the Convention.[904] This implies that all the countries in these regions, including West African countries must implement the obligations created by the

[900] UNCLOS. Available at: https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXI-6&chapter=21&Temp=mtdsg3&clang=_en.
[901] Ibid.
[902] Ibid. Estonia, Germany, Latvia, and Lithuania have acceded to UNCLOS. The rest are signatories and have ratified the Convention.
[903] Ibid. Germany and the United Kingdom of Great Britain and Northern Ireland have acceded to UNCLOS. The rest are signatories and have ratified the convention.
[904] Ibid.

Convention, particularly the duty to protect and preserve the environment, in the case of marine geoengineering. Alternatively, the obligation to protect and preserve the marine environment has attained the status of customary international law. Hence these States are under an obligation to comply with it.

The CBD is also widely adopted by the countries in these regions, thus making the provisions of the Convention as well as the resolutions adopted by the Contracting Parties on marine geoengineering activities apply in these regions.[905] All the countries located in the West African, Baltic Sea, North-East Atlantic, and Mediterranean Region are parties to the Convention.[906] Based on the doctrine of *pacta sunt servanda*,[907] obligations such as the duty to identify and monitor activities (including marine geoengineering) that could adversely impact biodiversity conservation and sustainability,[908] as well as the duty to conduct environmental impact assessment for proposed projects that could adversely impact biodiversity apply in these regions.[909] Furthermore, all the resolutions adopted by the Parties including decisions IX/16 and X/33 on marine geoengineering must be complied with in regions based on the principle of good faith.

Most countries equally widely subscribe to the UNFCCC, and the climate change obligations it creates apply to all Member States.[910] The UNFCCC has been subscribed to by all

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[905] Chapter Three of the Thesis provides an extensive discussion of this.
[906] CBD. Available at: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-8&chapter=27.
[907] Vienna Convention on the Law of Treaties, 23 May 1969, 1155 UNTS 331 (entered into force 27 January 1980), Art. 26.
[908] Convention on Biological Diversity, Art. 7.
[909] Convention on Biological Diversity, Art. 14.
[910] UNFCCC. Available at: https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXVII-7&chapter=27&Temp=mtdsg3&clang=_en. Likewise, all the countries in the Baltic Sea, North-East Atlantic Sea, Mediterranean Sea, and West African Region are parties to the Paris Agreement. Thus, the obligations imposed on parties to the Agreement by virtue of deploying geoengineering techniques (as discussed in Chapter three) apply. Paris Agreement. Available at: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-7-d&chapter=27&clang=_en.

countries in West Africa, Baltic Sea, North-East Atlantic Sea, and the Mediterranean Sea Region.[911] Thus, all the obligations including the obligation to adopt a precautionary approach in addressing climate change must be adhered to by all member States if they engage in marine geoengineering activities.[912] Likewise, the obligation to protect and enhance carbon sinks and reservoirs must not be lost on the countries within these regions if they decide to explore marine geoengineering. It is because activities of this nature pose significant risks to the sustainability of sinks and reservoirs.[913]

The situation is different for the London Convention and London Protocol. All the coastal states in the North-East Atlantic Sea and the Mediterranean Sea are parties to the London Convention.[914] In the case of the Baltic Sea, Russia, Estonia, Latvia, and Lithuania are not parties to the Convention.[915] In West Africa, four out of nineteen countries are parties to the London Convention.[916] Regarding the London Protocol, apart from Portugal, all the coastal states in the North-East Atlantic Sea region have ratified the London Protocol.[917] In the Baltic Sea region, Latvia, Lithuania, Portugal, and Russia are not parties to the London Protocol.[918] In the Mediterranean Sea region, France, Italy, and Spain are the only parties to the London Protocol.[919] In West Africa region, Ghana, Nigeria, and Sierra Leone are the only parties to the Protocol.[920] The low turnout in adopting the London Protocol and its amendments on marine geoengineering

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[911] UNFCCC. Available at: https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXVII-7&chapter=27&Temp=mtdsg3&clang=_en.
[912] UNFCCC, Art. 3(3).
[913] See UNFCCC, Art. 4(2)(a).
[914] London Convention. Available at: https://treaties.un.org/pages/showDetails.aspx?objid=08000002800fdd18.
[915] Ibid.
[916] Ibid. Cote d'Ivoire, Equatorial Guinea, Nigeria, and Sierra Leone are parties to the London Convention.
[917] International Maritime Organization, "Ratification by State". Available at: https://wwwcdn.imo.org/localresources/en/About/Conventions/StatusOfConventions/x-Status.xlsx.
[918] Ibid.
[919] Ibid.
[920] Ibid.

derails global efforts to govern marine geoengineering effectively. The apathy towards the London Protocol by West African countries leaves the sub-region handicapped in effectively governing marine geoengineering. The Contracting Parties to the London Protocol have adopted numerous resolutions which play significant roles in governing marine geoengineering activities.[921] Also, the dumping regime and amendments made to the London Protocol – albeit yet to enter into force - present the sub-region with a blueprint on how to develop a regional governance framework for marine geoengineering activities. Consequently, the passivity towards adopting the London Protocol and its amendments, especially by West African countries, stifles attempt at establishing a robust governance framework for marine geoengineering in the sub-region. As it will become evident in the next parts, the void created by the absence of a robust regional instrument or decision on marine geoengineering in West Africa could have been catered for (in the time being) by the inroads made by the Contracting Parties to the London Convention and London Protocol.

6.1.2 The Mechanisms Instituted by Regional Environmental Agreements

Carbon sequestration activities in the Baltic Sea are governed by the pollution regime of the Helsinki Convention and supplemented by the EU Directive (in the case of the EU Coastal States within the region). The Helsinki Convention establishes obligations and standards to ensure the protection of the marine environment in the Baltic Area.[922] It incorporates the Rio principles and admonishes the Contracting Parties to establish legislative, administrative, and other measures to protect and preserve the Baltic Sea.[923] The Coastal States constituting the Baltic Sea region are

[921] See chapter three for an elaborate discussion on marine geoengineering governance by the London Convention and London Protocol.
[922] Helsinki Convention, Art. 4(1).
[923] Helsinki Convention, Art. 3(1).

required to avoid introducing harmful substances into the sea[924] and are prohibited from dumping substances into the Baltic Area.[925] Besides the Helsinki Convention, the EU Directive establishes a legal framework for the sequestration of the environmentally safe geological sequestration of carbon in the region.[926] The EU is a party to the Helsinki Convention,[927] thus any permit issued according to the EU Directive ought to promote the efforts by the Convention to protect the region against the risk of eutrophication. The operation of these binding instruments in the Baltic Sea region helps to govern carbon sequestration activities in the region.

The North-East Atlantic Sea introduces binding obligations for the geological storage of carbon dioxide into the operative regional instruments. The OSPAR Convention is the operative regional instrument in North-East Atlantic and contains specific provisions on the geological storage of carbon dioxide streams in the region. In 2007, the Contracting Parties amended the OSPAR Convention to extend its operation to cover the regulation of carbon sequestration activities in the region.[928] In effect, these provisions on geological sequestration of carbon dioxide present the region with a valuable tool to regulate marine geoengineering activities. Additionally, the amendments, coupled with the general obligations to protect the North-East Atlantic Sea against pollution established by the OSPAR Convention, enhance the robustness of the region's governance regimes of marine geoengineering.

A framework treaty governs marine geoengineering activities in the Mediterranean Sea region – Barcelona Convention - which imposes general obligations to protect the marine environment in the region against pollution.[929] Being a framework treaty, the Convention

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[924] Helsinki Convention, Art. 5.
[925] Helsinki Convention, Art. 11(1).
[926] Directive 2009/31/EC, Art. 2(1).
[927] David Langlet, "Using the Continental Shelf for Climate Change Mitigation: A Baltic Sea Perspective" *supra* note 582, at 174.
[928] See OSPAR Commission, Amendments of Annex II and III, *supra* note 705.
[929] Barcelona Convention, Art. 4(1).

contains general obligations. Detailed protocols supplement the Convention, which spells out rules for dumping, specially protected areas and biodiversity, emergency cooperation, land-based pollution, seabed pollution, transboundary movement of hazardous waste, and integrated coastal zone management.[930] Also, rules from protocols supplement the Convention by spelling out obligations for dumping and land-based pollution. Besides this approach, the parties to the Convention have not attempted to negotiate and adopt a protocol that explicitly governs marine geoengineering or carbon sequestration activities in the Mediterranean Sea.

The Abidjan Convention is a framework treaty that imposes a general obligation on the Contracting States to protect the marine environment in West Africa. Like the Barcelona and Helsinki Conventions, the Abidjan Convention also uses its pollution regime to govern marine geoengineering activities. It imposes a general obligation on Contracting Parties to take appropriate measures to prevent, reduce, combat, and control pollution of the region.[931] However, unlike the other regional treaties, Abidjan Convention incorporates international rules and standards on dumping.[932] Thus, by the operation of this novel provision, the standards on ocean dumping developed by the London Convention and London Protocol apply in the region even though majority of West African countries are yet to become signatories to the Protocol. The Contracting States to the Abidjan Convention must comply with the standards on marine geoengineering developed by the Contracting Parties to the London Protocol since these rules and standards were developed according to the ocean dumping rules of the London Convention and London Protocol.[933]

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[930] See the UNEP website for context. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/31970/bcp2019_web_eng.pdf.
[931] Abidjan Convention, Art. 4.
[932] Abidjan Convention, Art. 6.
[933] See Chapter Three on the evolution of the rules and standards developed by the Contracting Parties to the London Convention and London Protocol on marine geoengineering.

Furthermore, the LBSA Protocol compliments the Abidjan Convention through the imposition of obligations to prevent, reduce, mitigate, and control pollution from land-based sources and activities on the territories of Contracting States or emanating from any other land-based sources.[934] Thus, these obligations apply to marine geoengineering activities such as OTEC and ocean alkalinization activities which involve a land-based component.

Besides these general obligations against pollution created by the Abidjan Convention and Protocol, there has not been an amendment to the Convention (as is the case in the OSPAR Convention) or the operation of an AU regulation on carbon sequestration (like in the Baltic Sea region). The general obligations against pollution created by the Convention and Protocols are the binding obligations on marine geoengineering in the sub-region.

6.1.3 The Use of Other Sources of Law Including Soft Law Instruments

The Baltic Sea Action Plan suggests that any marine geoengineering activity likely to compound the region's eutrophication challenge will likely face stiff opposition. Eutrophication is a major environmental threat in the Baltic Sea,[935] thus ocean fertilization involving nitrogen and phosphorus compounds as a catalyst to facilitate phytoplankton growth in the Baltic Sea is likely to face stiff opposition.

Furthermore, marine geoengineering techniques such as artificial downwelling and OTEC and techniques that employ geosynthetic containers in storing carbon dioxide in the ocean[936] are likely to be resisted. The Action Plan notes that activities that involve the laying of underwater cables and pipelines have adverse effects on the seabed.[937] Likewise, the use of

[934] LBSA Protocol, Art. 1.
[935] Baltic Sea Action Plan, *supra* note 612 at 6.
[936] Mark E. Capron et al., *supra* note 116.
[937] HELCOM Guidelines for Sea-Based Measures, *supra* note 654.

submerged objects such as geosynthetic containers (as in the case of marine geoengineering techniques involving carbon storage in the deep ocean, on the seabed, by the cultivation of macroalgal, or by depositing crop wastes in the deep ocean) causes physical obstructions on the seafloor and affects marine organisms like sea birds.[938]

The North-East Atlantic Region's Action Plan[939] does not refer to climate change or geoengineering. However, the Contracting Parties to the OSPAR Convention developed the OSPAR Guideline for Risk Assessment, which creates an avenue to examine the risk associated with geological carbon sequestration activities in the region.[940] The guideline establishes a permit regime for the geological sequestration of carbon dioxide. It prohibits any other activity carried out without the requisite authorization from the designated national authority.[941] Furthermore, it contains a generic risk assessment framework for geological carbon sequestration activities in the region, including post-injection risk assessments.[942] Thus, the guideline supplements the amendments to the OSPAR Conventions on the geological storage of carbon dioxide to establish a robust regional marine geoengineering governance regime in the North-East Atlantic Region.

Besides these significant developments in the North-East Atlantic, the Contracting Parties to the OSPAR Convention in 2008 adopted a resolution that prohibits the placement of carbon dioxide in water columns or on the seabed.[943] This prohibition exempts the placement of

[938] Mark E. Capron et al, *supra* note 116.
[939] Secretariat of the Coordinating Body on the Sea of East Asia (COBSEA) & United Nations Environment Programme (UNEP), "Regional Action Plan on Marine Litter" (2019). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/30162/RAPMALI_19.pdf?sequ%E2%80%A6. [COBSEA, Regional Action Plan on Marine Litte].
[940] OSCAR Commission, Annex 6, *supra* note 714.
[941] Ibid., para 3.1.
[942] OSPAR Guideline for Risk Assessment, *supra* note 695 at para. 6 and 7.
[943] OSPAR Commission, Annex 5, *supra* note 723 at preamble.

substances that comply with the aims of the OSPAR Convention.[944] Thus, the region possesses an ample array of soft law instruments to effectively oversee marine geoengineering activities, potentially serving as a benchmark in the establishment of a regional governance framework dedicated to marine geoengineering.

Unlike the other regions, the Mediterranean Sea lacks soft law instruments that specifically address marine geoengineering activities. The Stockholm Ministerial Conference and the Rio Summit influenced the preparation and adoption of the Mediterranean Action Plan Phase I and II.[945] The Action Plan makes one of its main priorities the prevention of pollution by dumping.[946] In this regard, it lists three activities that Contracting Parties must do to achieve this objective. The Coastal States in the Mediterranean Sea region are required to consolidate reports prepared from data collected on permits issued according to dumping activities.[947] The reports must be acted upon by the Contracting Parties.[948] The Contracting Parties are required to develop technical guidelines and requirements on disposal methodology and monitoring of disposal sites.[949] Finally, the Contracting Parties are required to assess the implementation of the Protocol on dumping and the efficiency of measures implemented.[950] Besides these specifications in the Action Plan, the region is yet to develop a technical guideline which provides for the disposal methodology and monitoring of disposal sites including dumping activities involving marine geoengineering.

The African Union has urged its members to focus on establishing a governance regime for marine geoengineering. However, evidence in the West African sub-region must show the

[944] Ibid., preamble.
[945] Peter M. Haas and Rodolfo Lewanski, *supra* note 741.
[946] UNEP Mediterranean Action Plan, *supra* note 737 Phase II, Appendix I at 117.
[947] Ibid., 124.
[948] Ibid.
[949] Ibid.
[950] Ibid.

attempts to develop a governance regime for marine geoengineering. The AU Strategic and Action Plan contains the most significant attempt thus far to develop a governance regime for marine geoengineering. In this document, the AU considered the potential of CCS and the need to develop a governance framework for geoengineering techniques for the continent.[951] It urged its members States to adopt an integrated governance approach in the regulation of the geological storage of carbon in the ocean through processes such as ocean alkalinization.[952] The AU observed that geoengineering governance at the regional level remains a challenge, hence it urged its members to contribute to the research, regulatory, and development of the technology at the global level.[953] The AU estimates that these contributions could ensure the consideration of the concerns, needs, and context of African countries in formulating policies, standards, and rules to govern the technology.[954]

The African continent and the West African subregion have yet to adopt any resolution on marine geoengineering activities. At the global level, a plethora of resolutions are in force under the CBD and London Protocol to govern marine geoengineering.[955] Likewise, in the North-East Atlantic the Contracting States to the OSPAR Convention adopted a resolution to prohibit the placement of carbon dioxide in water columns or on the seabed.[956] However, neither the climate change negotiating the structure of the AU nor the parties to the Abidjan Convention have adopted a resolution on marine geoengineering.

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[951] AU Climate and Resilient Development Strategy and Action Plan, *supra* note 14 at 20 and 44.
[952] Ibid.
[953] Ibid.
[954] Ibid.
[955] See Chapter Three for further discussion.
[956] OSPAR Commission, Annex 5, *supra* note 723 at preamble.

6.2 Future Directions

This thesis highlights the need for West African countries to adopt the London Protocol to enhance the governance of marine geoengineering activities on the continent. The London Protocol has made considerable progress in developing a governance framework for marine geoengineering. The West African region needs regional instruments tailored to govern marine geoengineering. Nevertheless, there is a growing interest and activities on geoengineering developing in the region. By adopting the London Protocol, the countries within the West African region could – in the meantime - implement the decisions and developments adopted by the London Protocol for marine geoengineering activities on the continent.

Also, either the AU or members of the Abidjan Convention need to consider the adoption soft law mechanisms such as resolutions to govern marine geoengineering. The continent and region lack soft law instruments tailored to govern marine geoengineering. It is a fact that the knowledge of geoengineering keeps developing with time. However, it is instructive to note that soft law instruments help govern technology without a binding international agreement on geoengineering. The region could use a similar approach in the time being to govern marine geoengineering activities on the continent.

Furthermore, where the region or continent decides on adopting binding obligations on marine geoengineering activities, the Abidjan Convention could either be amended to reflect these obligations or a protocol could be negotiated and adopted as part of the Abidjan Convention framework. The Abidjan Convention is a framework treaty; hence a protocol on marine geoengineering could be negotiated under the Convention.

At the global level, the CBD should proactively adapt to technological advancements by formulating additional resolutions. The CBD can better address emerging issues by providing comprehensive guidance and effective implementation. Aligning with the Kunming-Montreal Global Biodiversity Framework's Target 8,[957] the CBD might focus on minimizing climate change and ocean acidification impacts on biodiversity while enhancing ocean resilience through mitigation strategies. Considering marine geoengineering as a potential tool for achieving this target warrants thorough exploration and evaluation.[958]

The Ocean and Climate Change Dialogue under the UNFCCC might be used to discuss the role and impacts of marine geoengineering techniques on the environment. The Ocean and Climate Change Dialogue was first convened in 2020.[959] The Conference of Parties (COP), at its twenty-fifth session, requested the Subsidiary Body for Scientific and Technological Advice to convene a dialogue on the ocean and climate change to consider how to strengthen mitigation and adaptation action.[960] In the context of marine geoengineering governance, the COP could commission the Subsidiary Body for Scientific and Technological Advice to consider marine geoengineering as a climate change mitigation strategy. Based on the findings of the Subsidiary Body for Scientific and Technological Advice, the COP could shape the governance of these techniques to ensure that they fulfill the regime's object and comply with other regimes' efforts.

The IPCC's Working Groups II and III might address marine geoengineering in subsequent reports. The cardinal objective of the UNFCCC is to keep the atmospheric temperature below 2°C relative to pre-industrial levels,[961] thus it is important that the Working Groups present reports on the role, contributions, and impacts of each technique on the environment, including

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[957] Secretariat of the Convention on Biological Diversity, *Kunming-Montreal Global Diversity Framework*, CBD/COP/15/L.25, 18 December 2022. Available at: https://www.cbd.int/doc/c/e6d3/cd1d/daf663719a03902a9b116c34/cop-15-l-25-en.pdf.
[958] Ibid., Target 8.
[959] United Nations Climate Change, online: https://unfccc.int/event/ocean-and-climate-change-dialogue-to-consider-how-to-strengthen-adaptation-and-mitigation-action.
[960] United Nations Framework Convention on Climate Change, Report of the Conference of the Parties on its Twenty-Fifth Session held in Madrid from 2 to 15 December 2019, Decision 1/CP.25 (16 March 2020), para. 31.
[961] UNFCCC, Art. 2(1).

the impacts and contributions of each technique to climate change mitigation and adaptation. The reports from the experts could equip the Conference of Parties with an idea of how to govern marine geoengineering in accordance with the UNFCCC regime.

Furthermore, the Conference of Parties of UNFCCC might adopt decisions on marine geoengineering to enhance the governance of these techniques under the regime. The Ocean and Climate Change Dialogues and the reports from the Working Groups of the IPCC offer the COP avenues to understand the technicalities undergirding marine geoengineering, including the impacts of marine geoengineering on the environment and climate change efforts. The decisions on marine geoengineering by the COP of the CBD and London Protocol present the COP of the UNFCCC regime with a template of the role of decisions in shaping the governance of these techniques. In this regard, the COP of the UNFCCC regime might adopt decisions on marine geoengineering that comply with the objectives of the UNFCCC. In addition, the resolutions and decisions might consider the efforts made by Contracting Parties to CBD and London Convention in governing marine geoengineering.

The London Convention and Protocol is the principal multilateral environmental agreement governing marine geoengineering. However, the regime is saddled with some shortcomings. It is essential to acknowledge their limitations in governing all existing techniques. The creation of Annex 4 presents the Contracting Parties with a procedure for listing additional marine geoengineering techniques needed to be regulated. Presently, the Contracting Parties have prioritized five techniques: ocean fertilization, ocean alkalinization, macroalgae cultivation and other biomass, increasing ocean reflectivity, and marine cloud brightening.[962] However, there is doubt as to whether the amendments to the London Protocol cover marine geoengineering

[962] See International Maritime Organization (IMO), Resolution LO.4(8) Annex 4; International Maritime Organization, Resolution LC 44/17.

techniques such as marine cloud brightening which do not constitute "placement of matter" per article 6*bis*.[963] Additionally, the non-listing of other marine geoengineering techniques by Annex 4 of the London Protocol poses a challenge in the governance of these techniques. The prioritization of five marine geoengineering techniques casts uncertainty on the extent to which the London Protocol governs the non-prioritized techniques. The Contracting Parties might consider clarifying the extent to which the Protocol applies to the non-prioritized marine geoengineering techniques.

The Secretariat of the CBD might want to consider convening further workshops on marine geoengineering. The Secretariat of the CBD might want to involve representative from multiple regimes, including the London Protocol, UNFCCC, and the likes, in a workshop on marine geoengineering. This is likely to ensure that a holistic approach is instituted in governing marine geoengineering activities. The expertise from each regime on marine geoengineering will greatly benefit the international community in ensuring that these technologies do not aggravate or compound the existing problem -climate change.

The UNEA should revisit the issues on geoengineering in the draft resolution presented by Switzerland in 2019. By revisiting the issues on geoengineering, the international community would be afforded the opportunity to decide whether there is a need to govern marine geoengineering. The UNEA has been instrumental in negotiating treaties, including the Minamata Convention and the ongoing plastic treaty. Where it becomes apparent that there is a need to adopt a new agreement to govern these techniques, the UNFCCC regime could be an avenue to negotiate such an agreement as it is a framework treaty. However, the proposed

[963] International Maritime Organization, Resolution LC 44/17, Annex 16-17.

agreement could be negotiated as a standalone agreement like the Minamata Convention or the ongoing plastic treaty.

BIBLIOGRAPHY

TREATIES AND INTERNATIONAL AGREEMENTS

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 19 June 2023 C.N.203.2023 (entered into force 20 July 2023).

Articles of Association for the Establishment of an Economic Community of West Africa, 4 May 1967, 595 UNTS 287 (entered into force on 4 May 1967).

Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, 30 January 1991, 2101 UNTS 177 (22 April 1998).

Secretariat of the Convention on Biological Diversity, *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting*, UNEP/CBD/COP/DEC/X/33, 29 October 2010. Available at: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf.

Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region and Protocol, 23 March 1981, ILM Vol. 20, p. 746-76.

Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, 29 December 1972, 1046 UNTS 120 (entered into force 23 June 1977).

Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, 15 February 1972, 932 UNTS 3 (7 April 1974).

Convention for the Prevention of Marine Pollution from Land-Based Sources, 4 June 1974, 1546 U.N.T.S 103 (entered into force 6 May 1978).

Convention on the Protection of the Marine Environment of the Baltic Sea Area 22 March 1974, 1507 UNTS 166 (entered into force on 3 May 1980). Available at: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-5&chapter=27&clang=_en.

Directive 2009/31/EC of the European Parliament and of the Council on the Geological Storage of Carbon Dioxide and Amending Council Directive 85/337/ EEC, European Parliament and Council Directive 2000/60/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC, and Regulation (EX) No 1013/2006 [2009] OJ L140/114. Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF.

Kyoto Protocol to the United Nations Framework Convention on Climate Change, 11 December 1997, 2303 UNTS 162 (entered into force 16 February 2005).

Mediterranean Sea Region see, Convention for the Protection of the Mediterranean Sea Against Pollution (with annex and Protocols for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft and Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency), 16 February 1976 1102 UNTS 27 (12 February 1978). Available at: https://treaties.un.org/pages/showDetails.aspx?objid=08000002800f6a1c.

Minamata Convention on Mercury, 10 October 2013, 3202 UNTS 560 (entered into force 16 August 2017).

North-East Atlantic Region, see Convention for the Protection of the Marine Environment of the North-East Atlantic, 22 September 1992, 2354 UNTS 67 (entered into force 25 March 1998). Available at: https://treaties.un.org/pages/showdetails.aspx?objid=0800000280069bb5.

Paris Agreement to the United Nations Framework Convention on Climate Change, 12 December 2015, Treaty Reg No 54113 (entered into force 4 November 2016).

Protocol to the Convention on the Protection of Marine Pollution by Dumping of Wastes and Other Matter (adopted 7 November 1996; entered into force 24 March 2006).

Protocol to the Abidjan Convention Concerning Cooperation in the Protection and Development of Marine and Coastal Environment from Land-Based Sources and Activities in the Western, Central, and Southern African Region (adopted on 22 June 2012, not yet in force).

Statute of the International Court of Justice, 26 June 1945 33 UNTS 993 (entered into force 24 October 1945).

Treaty on the Functioning of the European Union [2008] OJ C115/47 (TFEU).

United Nations Convention on the Law of the Sea, 10 December 1982, 1833 UNTS 3 (entered into force 19 November 1994).

United Nations Framework Convention on Climate Change, 9 May 1992 1771 UNTS 107 (entered into force 21 March 1994).

United Nations Declaration on the Rights of Indigenous Peoples, GA Res 61/295, UNGAOR, 61st Sess, Supp No 53, UN Doc A/RES/61/295, 46 ILM 1013 (2007).

Vienna Convention on the Law of Treaties, 23 May 1969, 1155 UNTS 331 (entered into force 27 January 1980).

INTERNATIONAL DOCUMENTS

Agenda 21: Programme of Action for Sustainable Development; The Final Text of Agreements Negotiated by Governments at the United Nations Conference on Environment and Development (UNCED), 3-14 June 1992, Rio De Janeiro, Brazil. (New York, NY: United Nations Dept. of Public Information, 1993).

African Union, *Decision on the Report of the Coordinator of the Committee of African Heads of State and Government on Climate Change (CAHOSCC)* Assembly/AU/Dec.855 (XXXVI). Available at: https://au.int/sites/default/files/decisions/42725-Assembly_AU_Dec_839_-_865_XXXVI_E.pdf.

African Union, "Agenda 2063: The Africa We Want" (September 2015). Available at: https://au.int/sites/default/files/documents/36204-doc-agenda2063_popular_version_en.pdf.

African Union, "African Union Climate and Resilient Development Strategy and Action Plan (2022-2032)". Available at: https://www.tralac.org/documents/resources/african-union/4566-au-climate-change-and-resilient-development-strategy-and-action-plan-2022-2032/file.html.

African Union, "Meeting of the Committee of African Heads of State and Government on Climate Change (CAHOSCC)". Available at: https://au.int/en/newsevents/20220206/meeting-committee-african-heads-state-and-government-climate-change-cahoscc.

African Union, “Decisions & Declarations”. Available at: https://au.int/en/decisions/assembly%E2%80%8B.

African Union, “About the African Union”. Available at: https://au.int/en/overview.

African Group of Negotiators on Climate Change, “Structure and Membership of the AGN”. Available at: https://africangroupofnegotiators.org/about-the-agn/.

African Groups of Negotiators on Climate change, “AGN Submissions and Statements to the UNFCCC”. Available at: https://africangroupofnegotiators.org/document-library/agn-submissions-to-the-unfccc/.

African Ministerial Conference on the Environment, “Decision Adopted by Conference at its Fifth Session UNEP/AMCEN.5/3”. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/20559/Amcen_5_decisions.pdf?sequence=1&isAllowed=y.

African Ministerial Conference on the Environment, “Decision Adopted by the AMCEN at its Eight Session, UNEP/AMCEN/8/5 Annex II”. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/20583/Amcen_8_decisions.pdf?sequence=1&isAllowed=y.

Amendment to the Annexes to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, Concerning Disposal at Sea of Radioactive Wastes and other Radioactive Matter, IMO Res. LC.51/16 (1993) (adopted on 12 November 1993). Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LC.51(16).pdf.

Britannica, "West Africa', online: https://www.britannica.com/place/western-Africa.

Cabo Verde, "2020 Update to the First Nationally Determined Contribution (NDC)", (February 2020). Available at: https://www.geoengineeringmonitor.org/2022/05/quarterly-review-i-part-3-marine-geoengineering-ongoing-and-planned-open-ocean-trials-and-recent-developments-in-research/?print=pdf.

Declaration of the United Nations Conference on Environment and Development, UN Doc. A/CONF.151/26, (1992) 31 *International Legal Materials 874.*

Economic Community of West African States (ECOWAS), "ECOWAS Regional Climate Strategy (RCS) and Action Plan (2022-2030"). Available at: http://www.climatestrategy.ecowas.int/images/documentation/ECOWAS%20Regional%20Climate%20Strategy_adopted%20june%202022.pdf.

Economic Community of West African States (ECOWAS), *Supplementary Act A/SA.4/12/08 Relating to the ECOWAS Environmental Policy*. Available at https://ecowap.ecowas.int/media/ecowap/related-policy/ECOWEP_-_ECOWAS_Environmental_Policy_EN.pdf.

Economic Community of West African States (ECOWAS), "ECOWAS Renewable Energy Policy (2015)". Available at: http://www.ecreee.org/sites/default/files/documents/ecowas_renewable_energy_policy.pdf.

Economic Community of West African States (ECOWAS), "Intervention framework for climate-smart agriculture in the Sahel and West Africa in 2015 (see, Economic Community of West African States (ECOWAS), Intervention Framework for the Development of Climate-Smart Agriculture under the West Africa Regional Agricultural Policy (ECOWAP/CAADP) Implementation Process" (15-18 June 2015). Available at: http://www.hubrural.org/IMG/pdf/ecowas_ecowap_intervention_framework_for_csa_june_2015_final.pdf.

Economic Community of West African States (ECOWAS), "Strategic framework for the 2025 horizon of the ECOWAS Agricultural Policy in 2017 (see, Economic Community of West African States (ECOWAS), *2025 Strategic Policy Framework* (November 2017). Available at: https://faolex.fao.org/docs/pdf/eco191485.pdf.

Economic Community of West African States (ECOWAS), "ECOWAS Disaster Risk Reduction Gender Strategy and Action Plan 2020-2030" (28 April 2020)". Available at: https://www.gfdrr.org/sites/default/files/publication/ECOWAS%20GSAP_EN_Final.pdf.

Economic Community of West African States (ECOWAS), "Eighty-Sixth Ordinary Session of the ECOWAS Council of Ministers to hold in Accra" (15 June 2021). Available at: https://ecowas.int/eighty-sixth-ordinary-session-of-the-ecowas-council-of-ministers-to-hold-in-accra/#:~:text=The%20Eighty%2DSixth%20Ordinary%20Session,Movenpick%20Hotel%20in%20Accra%2C%20Ghana.

HELCOM, "Baltic Sea, online: http://stateofthebalticsea.helcom.fi/in-brief/our-baltic-sea/#:~:text=Our%20Baltic%20Sea,-Home%20In%20brief&text=The%20Baltic%20Sea%20is%20surrounded,a%20source%20of%20human%20livelihood.

HELCOM, "Baltic Sea Action Plan" 2021 update, online: https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf.

HELCOM, Baltic Sea Action Plan, 2021 Update (October 2021), online: https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf.

HELCOM, "Guidelines for Sea-Based Measures to Manage Internal Nutrient Reserves in the Baltic Sea Region" (October 2021), online: https://helcom.fi/wp-content/uploads/2021/10/Guidelines-for-Sea-Based-Measures-to-Manage-Internal-Nutrient-Reserves-in-the-Baltic-Sea-Region.pdf.

HELCOM, "Implementation of the 2007 Baltic Sea Action Plan" (2021). Available at: https://helcom.fi/wp-content/uploads/2021/10/Implementation-of-the-2007-BSAP-v6-211012.pdf.

Indigenous Peoples' Global Summit on Climate Change, *The Anchorage Declaration (24 April 2009),* online: https://unfccc.int/resource/docs/2009/smsn/ngo/168.pdf.

Intergovernmental Panel on Climate Change (IPCC), *Climate Change Synthesis Report Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* [Watson, R. T. and the Core Writing Team (eds)] (Cambridge University Press, Cambridge, United Kingdom, and New York, US, 2001) 339. Available at: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_TAR_full_report.pdf.

Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Impacts, Adaptation, and Vulnerability, Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* [James J. McCarthy, Osvaldo F. Canziani, Neil A. Leary, David J. Dokken, and Kasey S. White (eds.)] (Cambridge, Cambridge University Press, 2001). Available at: https://www.ipcc.ch/site/assets/uploads/2018/03/WGII_TAR_full_report-2.pdf.

Intergovernmental Panel on Climate Change (IPCC), *Climate Change and Biodiversity*, IPCC Technical Paper V., [Habiba Gitay, Avelino Suarez, Robert T. Watson, and David Jon Dokken (eds.)] (IPCC, 2002). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/32705/CCB.pdf?sequence=1&isAllowed=y.

Intergovernmental Panel on Climate Change (IPCC), *Special Report on Carbon Dioxide Capture and Storage Prepared by Working Groups III to the Intergovernmental Panel on Climate Change,* [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)] (Cambridge University Press, Cambridge, United Kingdom, and New York, US, 2005) 442, online: https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_wholereport-1.pdf.

Intergovernmental Panel on Climate Change (IPCC), Climate Change 2014: Synthesis Report. Contribution of Working Group I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, [P. K. Pachauri and L. A. Meyer (eds.)] (Geneva: World Meteorological Organization, 2014). Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.

Intergovernmental Panel on Climate Change (IPCC), Climate Change 2014: Mitigation of Climate Change Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E.

Intergovernmental Panel on Climate Change (IPCC) , IPCC Special Report on the Ocean and Cryosphere in a Changing Climate , [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)] (Cambridge: Cambridge University Press, 2019) 755, online: https://www.ipcc.ch/site/assets/uploads/sites/3/2022/03/SROCC_FullReport_FINAL.pdf.

International Maritime Organization, "Ratification by State", online: https://www.imo.org/en/About/Conventions/Pages/StatusOfConventions.aspx.

International Maritime Organization, Report of the Fourteenth Meeting of the Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution, Resolution LP.5(14) (11 October 2019). Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LP.5(14).pdf.

International Maritime Organization, *Report of the Forty-Fourth Consultative Meeting and the Seventeenth Meeting of Contracting Parties*, Resolution LC 44/17 (20 October 2022).

International Maritime Organization, Report of the Forty-Fifth Consultative Meeting of Contracting Parties to the London Convention & Eight Meeting of Contracting Parties to the London Protocol, Resolution LC 45/2 (27 June 2023).

International Maritime Organization, Report of the Forty-Fifth Consultative Meeting of Contracting Parties to the London Convention & Eight Meeting of Contracting Parties to the London Protocol, Resolution LC 45/25/1(30 June 2023).

International Maritime organization, *The First Meeting of Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter 1972*, Resolution LP.1(1) (adopted on 2 November 2006). Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LP.1(1).pdf.

International Maritime Organization (IMO), "The London Convention and Protocol", online: https://www.imo.org/en/KnowledgeCentre/ConferencesMeetings/Pages/London-Convention-Protocol.aspx.

International Maritime Organization (IMO), *Convention on the Prevention of marine Pollution by Dumping of Wastes and other Matter, 1972 and its 1996 Protocol*, LC-LP.1/Circ. 14, 13 July 2007 (adopted on 13 July 2007). Available at: https://www.whoi.edu/cms/files/London_Convention_statement_24743_29324.pdf.

International Maritime Organization (IMO), *The Thirtieth Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol,* Resolution LC-LP.1 (2008) (Adopted on 31 October 2008). Available at:

https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LC-LP.1%20(2008).pdf.

International Maritime Organization (IMO), *The Thirtieth Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol,* Resolution LC-LP.1 (2008) Adopted on 31 October 2008. Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LC-LP.1%20(2008).pdf.

International Maritime Organization (IMO), *The Fourth Meeting of Contracting Parties to the 1996 Protocol of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other matter 1972,* Resolution LP.3(4) (Adopted on 30 October 2009). Available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Resolution%20LP-3(4).doc.

International Maritime Organization (IMO), "United Nations Convention on the Law of the Sea". Available at: https://www.imo.org/en/ourwork/legal/pages/unitednationsconventiononthelawofthesea.aspx#:~:text=The%20United%20Nations%20Convention%20on,the%20oceans%20and%20their%20resources.

International Maritime Organization, "Maps of Parties to the London Convention/Protocol". Available at:

https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/LC_LP/Map%20of%20Parties%202022.pdf.

International Maritime Organization, "Ratification by State", online: https://wwwcdn.imo.org/localresources/en/About/Conventions/StatusOfConventions/x-Status.xlsx.

International Maritime Organization (IMO), *The Eight Meeting of Contracting Parties to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter 1972,* Resolution LP.4(8), Annex 4. Available at: https://www.gc.noaa.gov/documents/resolution_lp_48.pdf.

International Maritime Organization (IMO), *The Thirty-Second Consultative Meeting of the Contracting Parties to the London Convention and the Fifth Meeting of the Contracting Parties to the London Protocol,* Resolution LC-LP.2 (2012) (Adopted on 14 October 2010). Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LC-LP.2(2010).pdf.

International Maritime Organization (IMO) "Ocean Fertilization under the LC/LP", online: https://www.imo.org/en/OurWork/Environment/Pages/OceanFertilization-default.aspx.

Intergovernmental Oceanographic Commission of UNESCO, Report on the IMO London Convention Scientific Group Meeting on Ocean Fertilization, IOC/INF-1247 (15 June 2008). Available at: https://unesdoc.unesco.org/ark:/48223/pf0000160478?posInSet=1&queryId=N-EXPLORE-c03428aa-09ad-4607-af75-b26f2d865949.

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (2019), "High Level Review of a Wide Range of Proposed Marine Geoengineering Techniques" (2019) Boyd, P.W. and Vivian, C.M.G. (eds.) Rep. Stud. GESAMP No. 98. Available at: http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques.

Mediterranean Experts on Climate and Environmental Change (MedECC), *Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future.* First Mediterranean Assessment Report [Cramer, W., Guiot, J., Marini, K. (eds.)] (Marseille, France: Union for the Mediterranean, 2020). Available at: https://www.medecc.org/wp-content/uploads/2021/05/MedECC_MAR1_complete.pdf.

National Academy of Science, *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (Washington: National Academies Press, 1992). Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjIo_bGrbSAAxWsjokEHf7PB1MQFnoECBsQAQ&url=https%3A%2F%2Fnap.nationalacademies.org%2Fcatalog%2F1605%2Fpolicy-implications-of-greenhouse-warming-

mitigation-adaptation-and-the-science&usg=AOvVaw381xPOb_8Q20VOM4JEsERm&opi=89978449.

National Academy of Sciences *Policy, Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (Washington: National Academy Press, 2009). Available at: https://nap.nationalacademies.org/read/1794/chapter/1.

National Research Council, *Climate Intervention: Reflecting Sunlight to Cool the Earth* (The National Academies Press, 2015b), online: https://nap.nationalacademies.org/read/18988/chapter/1.

National Research Council, *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration (*2015, The National Academies Press). Available at: https://nap.nationalacademies.org/read/18805/chapter/1#ii.

OSPAR Commission, "About OSPAR", online: https://www.ospar.org/about#:~:text=OSPAR%20is%20the%20mechanism%20by,the%20Paris%20Convention%20of%201974.

OSPAR Commission, *OSPAR Guideline for Risk Assessment and Management of Storage of CO2 Streams in Geological Formations,* Reference Number: 2007-12. Available at: https://www.ospar.org/documents?d=32760.

OSPAR Commission, *Amendments of Annex II and Annex III to the Convention in relation to the Storage of Carbon Dioxide Streams in Geological Formations*, ANNEX 4 (Ref. §2.10a), OSTEND: 25-29 JUNE 2007. Available at: https://www.ucl.ac.uk/cclp/pdf/OSPAR2007-Annex-4.pdf.

OSPAR Commission, "Ratification of OSPAR Carbon Capture and Storage Measure", online: https://www.ospar.org/site/assets/files/1501/ospar_pr_11_ratification_of_ccs_measure_en.pdf.

OSPAR Commission, *OSPAR Decision 2007/2 on the Storage of Carbon Dioxide Streams in Geological Formations*, Annex 6 (Ref. §2.10c), OSTEND: 25-29 JUNE 2007. Available at: https://www.nlog.nl/sites/default/files/decision%202007_2_co2_storage.doc.

OSPAR Commission, *OSPAR Decision 2007/01 To Prohibit the Storage of Carbon Dioxide Streams in the Water Column or on the Sea-bed, OSPAR 07/25/1,* Annex 5, 15 January 2008. Available on: https://www.ospar.org/documents?v=32641.

Republic of Mauritius, "Update of the Nationally Determined Contribution of the Republic of Mauritius" (01 October 2021). Available at: https://unfccc.int/sites/default/files/NDC/2022-06/Final%20Updated%20NDC%20for%20the%20Republic%20of%20Mauritius%2001%20October%202021.docx.

Republic of Rwanda, "Updated Nationally Determined Contribution" (May 2020). Available at: https://unfccc.int/sites/default/files/NDC/2022-06/Rwanda_Updated_NDC_May_2020.pdf.

Scientific Group's Intersessional Technical Working Group, Risk Assessment and Management Framework for CO2 Sequestration in Sub-Seabed Geological Structures, LC/SG-CO2 1/7, annex 3. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi_vMnU_P_-AhWDFFkFHZLlBnAQFnoECBkQAQ&url=https%3A%2F%2Fwwwcdn.imo.org%2Flocalresources%2Fen%2FOurWork%2FEnvironment%2FDocuments%2FCO2SEQUESTRATIONRAMF2006.doc&usg=AOvVaw1bFH29h2QYxNUZsb3QzOzx.

Secretariat of the Convention on Biological Diversity *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters*, CBD Technical Series No. 66, Montreal, 2012.

Secretariat of the Convention on Biological Diversity, *Linkages Between Biological Diversity and Climate Change: Advice on the Integration of Biological Considerations into the Implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol,* CBD Technical Series No. 10, Montreal, 2003, Available at: https://www.cbd.int/doc/publications/cbd-ts-10.pdf.

Secretariat of the Convention on Biological Diversity, *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Ninth Meeting*, UNEP/CBD/COP/DEC/IX/16, 9 October 2008, at 7. Available at: https://www.cbd.int/doc/decisions/cop-09/cop-09-dec-16-en.pdf.

Secretariat of the Convention on Biological Diversity, *Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity*, CBD Technical Series No. 45, Montreal, 2009. Available at: https://www.cbd.int/doc/publications/cbd-ts-45-en.pdf.

Secretariat of the Convention on Biological Diversity, *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting*, UNEP/CBD/COP/DEC/X/33, 29 October 2010. Available at: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf.

Secretariat of the Convention on Biological Diversity, *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters*, CBD Technical Series No. 66, Montreal, 2012, p.12. Available at: https://www.cbd.int/doc/publications/cbd-ts-66-en.pdf.

Secretariat of the Convention on Biological Diversity, *Update on climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework*, CBD Technical Series No. 84, Montreal, 2016, p.12. Available at: https://coherent-commons.s3.amazonaws.com/artifacts/file/file/db46d9ba-5423-4a90-a9c8-2043f1f444f3.pdf?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIA23B6R4NTCRHS5NZ3%2F20230518%2Fus-east-

2%2Fs3%2Faws4_request&X-Amz-Date=20230518T170010Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=9de6b4e25330213ec41733f583c4c648039e90cb0905b58bbacbd89d5513c857.

Secretariat of the Convention on Biological Diversity, *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Eleventh Meeting*, UNEP/CBD/COP/DEC/XI/20, 5 December. Available at: https://www.cbd.int/doc/decisions/cop-11/cop-11-dec-20-en.pdf.

Secretariat of the Coordinating Body on the Sea of East Asia (COBSEA) & United Nations Environment Programme (UNEP), "Regional Action Plan on Marine Litter" (2019). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/30162/RAPMALI_19.pdf?sequ%E2%80%A6.

Secretariat of the Convention on Biological Diversity, *Kunming-Montreal Global Diversity Framework*, CBD/COP/15/L.25, 18 December 2022. Available at: https://www.cbd.int/doc/c/e6d3/cd1d/daf663719a03902a9b116c34/cop-15-l-25-en.pdf.

Stockholm Declaration of the United Nations Conference on the Human Environment (1972) 11 International Legal Materials 1416.

Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), *Technical and Regulatory Matters on Geoengineering in Relation to the Convention on Biological Diversity*, UNEP/CBD/SBSTTA/16/10, 12 March 2012. Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/official/sbstta-16-10-en.pdf.

Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), *Technical and Regulatory Matters on Geoengineering in Relation to the Convention on Biological Diversity*, UNEP/CBD/SBSTTA/16/10, 12 March 2012. Available at: https://www.cbd.int/doc/recommendations/sbstta-16/sbstta-16-rec-09-en.pdf.

Subsidiary Body on Scientific Technical and Technological Advice, *Regulatory Framework for Climate-Related Geoengineering Relevant to the Convention on Biological Diversity*, UNEP/CBD/SBSTTA/16/INF/29, 2 April 2012. Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-29-en.pdf.

Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), *Impacts of Climate-Related Geoengineering on Biological Diversity*, UNEP/CBD/SBSTTA/16/INF/28, 5 April 2012. Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-28-en.pdf.

Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA), *Impacts of Climate-Related Geoengineering on Biodiversity: Views and Experiences of Indigenous and Local Communities and Stakeholders* UNEP/CBD/SBSTTA/16/INF/30, 17 April 2012.

Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-30-en.pdf.

Subsidiary Body on Scientific Technical and Technological Advice, *Regulatory Framework for Climate-Related Geoengineering Relevant to the Convention on Biological Diversity*, UNEP/CBD/SBSTTA/16/INF/29, 2 April 2012. Available at: https://www.cbd.int/doc/meetings/sbstta/sbstta-16/information/sbstta-16-inf-29-en.pdf.

The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "SRM Engagement Workshop in Cotonou, Benin" (2019), online: https://www.degrees.ngo/events/benin-august-2019/.

The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Marin Biogeochemistry and Sea Level in the Gulf of Guinea" (2023), online: https://www.degrees.ngo/dmf/the-projects/benin-2023/.

The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Exploring Changes to the Harmattan Windy Season and Precipitation in Southern West Africa" (2023), online: https://www.degrees.ngo/dmf/the-projects/ghana-2023/.

The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Exploring Whether SRM Could Offset Droughts in West Africa" (2023), onlinet: https://www.degrees.ngo/dmf/the-projects/mali-2023/.

The Developing Country Governance Research and Evaluation for SRM (Degrees) Initiative, "Assessing the Effects of SRM on Crops in West Africa" (2023), online: https://www.degrees.ngo/dmf/the-projects/nigeria-2023/.

The Declaration of the United Nations Conference on the Human Environment, 1972.

The United Kingdom of Great Britain and Northern Ireland House of Commons Science and Technology Committee, *The Regulation of Geoengineering – Science and Technology Committee.* Available at: https://publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/22105.htm#a6.

United States of America, House of Representatives, *Committee on Science and Technology*, 108th Congress, 1st and 2nd Sess, No. 111-62, 111-75 and 111-88 (5 November 2009, 4 February 2010, and 18 March 2010) at 221, Available at: https://www.govinfo.gov/content/pkg/CHRG-111hhrg53007/pdf/CHRG-111hhrg53007.pdf.

United Nations, "Goal 14: Conserve and Sustainably Use the Oceans, Seas, and Marine Resources for Sustainable Development", online: https://sdgs.un.org/goals/goal14.

United Nations Climate Change, online: https://unfccc.int/event/ocean-and-climate-change-dialogue-to-consider-how-to-strengthen-adaptation-and-mitigation-action.

United Nation Environment Assembly, “Resolution for Consideration at the 4th United Nations Environment Assembly: Geoengineering and its Governance” submitted by Switzerland and supported by Burkina Faso, Federal States of Micronesia, Georgia, Liechtenstein, Mali, Mexico, Montenegro, Niger, Republic of Korea, and Senegal. Available at: https://geoengineering.environment.harvard.edu/files/sgrp/files/draft_unea_resolution.pdf.

United Nations Environment Programme, “Historic Day in the Campaign to Beat Plastic Pollution: Nations Commit to Develop a Legally Binding Agreement”, online: https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop.

United Nations Environment Programme, “North-East Atlantic”, onlinet: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/north-east?_ga=2.71224272.1182785317.1685373426-2059025123.1684457857.

United Nations Environment Programme, “Regional Seas Programme”. Online: https://www.unep.org/explore-topics/oceans-seas/what-we-do/regional-seas-programme.

United Nations Environment Programme/ Mediterranean Action Plan, *Mediterranean Strategy for Sustainable Development 2016-2025* (2016). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/7700/-

Mediterranean_strategy_for_sustainable_development_2016-2025_Investing_in_environmental_sustainability_to_achieve_social_and_economic_development-20.pdf?sequence=3.

United Nations Environment Programme "Mediterranean: Mediterranean Action Plan". Available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/mediterranean?_ga=2.212304276.1862929123.1685722035-1533237930.1680052584&_gac=1.147079749.1684684490.CjwKCAjw36GjBhAkEiwAKwIWyaCaV4kHZ-EpVOzPmU1HLVEKDAxN4ZJ4XGBQXFEj3RQACtwmitsh3RoCOLUQAvD_BwE.

United Nations Environment Programme. *Report of the Ninth Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against Pollution and its Protocols*, UNEP(OCA)/MED IG.5/16. Athens: UNEP; 1995. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi4vIe1-7T_AhW1j4kEHQTIBxsQFnoECAkQAQ&url=https%3A%2F%2Fwedocs.unep.org%2Fbitstream%2Fhandle%2F20.500.11822%2F2972%2F95ig5_16_eng.pdf&usg=AOvVaw02fj31rP0ucG8uUrrT1xmp.

United Nations Environment Programme, "About AMCEN". Available at: https://www.unep.org/regions/africa/african-ministerial-conference-environment/about-amcen.

United Nations Environment Programme, “AMCEN Past Sessions”. Available at: https://www.unep.org/regions/africa/african-ministerial-conference-environment/amcen-past-sessions .

United Nations Environment Programme, “West and Central Africa”, available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/west-and.

United Nations Framework Convention on Climate Change, Report of the Conference of the Parties on its Twenty-Fifth Session held in Madrid from 2 to 15 December 2019, Decision 1/CP.25 (16 March 2020).

JURISPRUDENCE

Legality of the Threat or Use of nuclear weapons, Advisory Opinion of 8 July 1996, [1996] ICJ Rep 226, [29].

Military and Paramilitary Activities and Against Nicaragua (Nicaragua v United States of America), [1986] ICJ Rep 14, para. 212 and 213.

MOX Plant (Ireland v. United Kingdom), Provisional Measures, Order of 3 December 2001, ITLOS Reports 2001, p. 95, para. 82.

The Southern Bluefin Tuna cases (New Zealand v. Japan; Australia v. Japan), Provisional Measures, 27 August 1999, ITLOS Reports 1999, p. 295, para 120; Chago Marine Protected Area Arbitration (Mauritius v United Kingdom) [2015] para 238, available at: https://pca-cpa.org/en/cases/11/.

Trail smelter case (United States, Canada) (1905 – 1982) VOL. III Reports of International Arbitral Awards at 77.

SECONDARY MATERIAL (MONOGRAPH)

Alan Boyle & Catherine Redgwell, *International Law and the Environment* (Oxford: Oxford University Press, 2021).

David Langlet, "Using the Continental Shelf for Climate Change Mitigation: A Baltic Sea Perspective" in *Regulatory Gaps in Baltic Sea Governance* (Switzerland: Springer International Publishing AG, 2018).

David I. Stern, Peter W. Gething, Caroline W. Kabaria, William H. Temperley, Abdisalan M. Noor, Emelda A. Okiro, Dennis G. Shanks, Robert W. Snow, Simon I. Hay, & Mathew Baylis, "Temperature and malaria trends in highland East Africa" (2011) 6:9 PloS One e24524-e24524.

David L. VanderZwaag, “The International Control of Ocean Dumping: Navigating from Permissive to Shores” in *Research Handbook on International Marine Environmental Law* (Northampton: Edward Elgar Publishing, 2015).

Elise Johansen, Signe Veierud Signe, & Ingvild Ulrikke Jacobsen, “Law of the Sea Responses to Sea-Level Rise and Threatened Maritime Entitlements: Applying an Exception Rule to Manage an Exception Situation” in *The Law of the Sea and Climate Change* (United Kingdom: Cambridge University Press: 2020).

Elise Johansen, “Ocean Feralization” in *The Law of the Sea and Climate change: Solutions and Constraints* (U.K.: Cambridge University Press, 2020).

Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C.
Minx (eds.)] (Cambridge: Cambridge University Press, 2014). Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_frontmatter.pdf.

Henrik Ringbom, Brita Bohman, & Saara Llvessalo,, “Combatting Eutrophication in the Baltic Sea: Legal Aspects of Sea-Based Engineering Measures: Legal Perspective (Leiden: Brill NV, 2019).

Isabelle Niang, Mohamed Abdrado, Essel Ama, Chris Lennard, & Ibidun O. Adelekan, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects*. Contribution of

Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)] (Cambridge: Cambridge University Press, 2014).

J. J. Lowe and M. J. C. Walker, *Reconstructing Quaternary Environment* (London: Longman, 1988).

K. Zweigert & H. Kotz, *An Introduction to Comparative Law* (Oxford: Oxford University Press, 1998).

Karen N Scott, "Mind the Gap: Marine Geoengineering and the Law of the Sea" in Robert C Beckman et al., eds, High Seas Governance: Gaps and Challenges (Leiden: Brill Neijhoff, 2019).

Karen N. Scott, "Geoengineering and the Marine Environment" in Rosemary Rayfuse, ed, Research Handbook on International Marine Environmental Law (Cheltenham, UK: Edward Elgar, 2015).

Kerryn Brent, *Governance of Marine geoengineering* (Ontario, Canada: Centre for International Governance Innovation, 2019).

Kerryn Brent., “Marine Geoengineering Governance and the Importance of Compatibility with the Law of the Sea” in *Research Handbook on Climate Change, Oceans and Coasts* (United Kingdom: Edward Elgar Publishing Limited, 2020).

Meinhard Doelle, *From Hot Air to Action? Climate Change, Compliance, and the Future of International Environmental Law* (Toronto: Carswell, 2005).

Michael Gilek, Mikael Karlsson, Sebastian Linke, & Katarzyna Smolarz, “Environmental Governance of the Baltic Sea: Identifying Key Challenges, Research Topics and Analytical Approaches” in *Environmental Governance of the Baltic Sea* (Switzerland: Springer International Publishing AG, 2016).

Nulifer Oral, *Regional Cooperation and Protection of the Marine Environment under International Law: The Black Sea* (Boston: BRILL, 2013).

Peter M. Haas and Rodolfo Lewanski, *Saving the Mediterranean: The Politics of International Environmental Cooperation* (New York: Columbia University Press, 1990).

Robert Cryer, Tamara Hervey, & Bal Sokhi-Bulley, *Research Methodologies in EU and International Law* (Oxford: Hart Publishing, 2011).

Robert A. Berner, *The Phanerozoic Carbon Cycle* (New Yor, Oxford University Press, 2004).

Shylesh Muralidharan, "Assessment of Ocean Thermal Energy Conversion", (2012) MSc Thesis, Massachusetts Institute of Technology, online: http://dspace.mit.edu/handle/1721.1/76927#files-area.

Willam C. G. Burns, *The Paris Agreement and Climate Geoengineering Governance: The Need for a Human Rights-Based Component* (Ontario: Centre for International Governance Innovation, 2016).

SECONDARY MATERIAL (ARTICLES)

A. Oschlies, M. Pahlow, A. Yool, & R. J. Matear, "Climate Engineering by Artificial Ocean Upwelling Channeling the Sorcerer's Apprentice: Ocean Pipe Impacts" (2010) 37:4 Geophysical Research Letters 1-5.

A. Oschlies, W. Koeve, W. Rickels, & K. Rehdanz, "Side Effects and Accounting Aspects of Hypothetical Large-Scale Southern Ocean Iron Fertilization" (2010) 7 Biogeosciences 4017 - 4035.

A. R. Thurber, A. K. Sweetman, B. E. Narayanaswamy, D. O. B. Jones, J. Ingels, & R. L. Hansman, "Ecosystem Function and Services Provided by the Deep Sea" (2014) 11:14 Biogeosciences 3941-3963.

Adam Lockyer & Jonathan Symons, “The National Security Implications of Solar Geoengineering: An Australian Perspective” (2019) 73:5 Australian Journal of International Affairs 485-503.

Adrian E Raftery, Alec Zimmer, Dargan M. W. Frierson, Richard Startz, & Peiran Liu, “Less than 2oC warming by 2100 unlikely” (2017) 7 Nature Climate Change 637.

Alan E. Boyle, “Protecting the Marine Environment: Some Problems and Developments in the Law of the `Sea” (1992) 16:2 Marine Policy 79-85.

Alan Robock, “Bubble, Bubble, Toil and Trouble: An Editorial Comment” (2011) 105:3-4 Climate Change 383-385.

Alex Aziz, Helen C. Hailes, John M. Ward, & Rulian R. G. Julian, “Long-term Stabilization of Reflective Foams in Sea Water” (2014) 4:95 Advances 5328-5336.

Andrew Glikson, “The Methane Time Bomb” (2018) 146 Energy Procedia 23-29.

Andrew Lockley, “Comment on “Review of Methane Mitigation Technologies with Application to Rapid Release of Methane from the Arctic”” (2012) 46:24 Environmental Science & Technology 13552-13553. Available on: https://pubs.acs.org/doi/10.1021/es303074j.

Andrew Yool, John G. Shepherd, Harry L. Bryden, & Andreas Oschlies, "Low Efficiency of Nutrient Translocation for Enhancing Oceanic Uptake of Carbon Dioxide" (2009) 114:C8 Journal of Geophysical Research C08009-n/a.

Anja Chalmin, "Geoengineering Projects in Africa Intensify Along with Oil and Gas Expansion" (7 November 2022). Available at: https://www.geoengineeringmonitor.org/2022/11/geoengineering-projects-in-africa-intensify-along-with-oil-and-gas-expansion/?print=pdf.

Anja Chalmin, "Geoengineering- Ongoing and Planned Open-Ocean Trials and Recent Developments in Research" (6 May 2022). Available at: https://www.geoengineeringmonitor.org/2022/05/quarterly-review-i-part-3-marine-geoengineering-ongoing-and-planned-open-ocean-trials-and-recent-developments-in-research/?print=pdf.

Antti-llari Partanen, Harri Kokkola, Sami Romakkaniemi, Veli-Matti Kerminen, Karl E. J. Lehtinen, Tommi Bergman, Antti Arola, & Hannele Korhonen, "Direct and Indirect Effects of Sea Spray Geoengineering and the Role of Injected Particles Size: Sea Spray Geoengineering" (2012) 117:D2 Journal of Geophysical Research: Atmosphere 1-17.

B. A. Seibel and P. J. Walsh, "Carbon Cycle: Potential Impacts of CO2 Injection on Deep-sea Biota" (2001) 294:5541 Science 319-320.

Brian Kirke, “Enhancing Fish Stocks with Wave-powered Artificial Upwelling” (2003) 46:9 Ocean & Coastal Management 901-915.

C. Branson, “A Green Herring: How Current Ocean Fertilization Regulation Distracts from Geoengineering Research” (2014) 54:1 Santa Clara Law Review 163.

C. M. Moore, M. M. Mills, K. R. Arrigo, I. Berman-Frank, L. Bopp, P. W. Boyd, E. D. Galbraith, R. J. Geider, C. Guieu, S .L. Jaccard, T. D. Jickells, J. La Roche, T. M. Lenton, N. M. Mahowald, E. Maranon, I. Marinov, J. K. Moore, T. Nakatsuka, A. Oschiles, M. A. Saito, T. F. Thingstad, A. Tsuda, O. Ulloa, “Processes and Patterns of Oceanic Nutrient Limitation” (2013) 6 *Nature Geoscience* 701 – 710.

C. N. Murray, L. Viisintini, G. Bidoglio, & B. Henry, “Permanent Storage of Carbon Dioxide in the Marine Environment: The Solid CO2 Penetrator” (1996) 37:6-8 Energy Conversion and Management 1067-1072.

C. S. Law, “Predicting and Monitoring the Effects of Large-Scale Ocean Iron Fertilization on Marine Trace Gas Emissions” (2011) 364 Marine Ecology Progress Series 283 – 288.

Calum Brown, “Achievement of Paris Climate Goals unlikely due to time lags in the land system” (2019) 9 Nature Climate Change 203.

Calvyn F. A. Sondak, Put O. Ang, John Beardall, Alecia Bellgrove, Sung Min Boo, Grevo S. Gerung, Christopher D. Hepburn, Dang Diem Hong, Zhengyu Hu, Hiroshi Kawai, Danilo Largo, Jin Ae Lee, Phaik-Eem Lim, Jaruwan Mayakun, Wendy A. Nelson, Jung Hyun Oak, Siew-Moi Phang, Sahoo Dinabandhu Sahoo, Yuwadee Peerapornpis, Yufeng Yang, & IK Kyo Chung, "Erratum to: Carbon Dioxide Mitigation Potential of Seaweed Aquaculture Beds" (2017) 29:5 Journal of Applied Phycology 2375-2376.

Carlos M. Duarte, Jiaping Wu, Xi Xiao, Annette Bruhn, & Dorte Jensen, "Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation" (2017) 4 Frontiers in Marine Science 1-8.

Carolyn D. Ruppel and John D. Kessier, "The Interaction of Climate Change and methane Hydrates" (2017) 55:1 Reviews of Geophysics 126-168.

Cesare Marchetti, "On Geoengineering and the CO2 Problem" (1977) 1:1 Climate Change 59-68.

Charles G. Trick, Brian D. Bill, William P. Cochan, Mark L. Wells, Vera L. Trainer, & Lisa D. Pickell, "Iron Enrichment Stimulates Toxic Diatom Production in High-Nitrate, Low-Chlorophyll Areas" (2010) 107:13 *Proceedings of the National Academy of Sciences of the United States of America* 5887-5892.

Chiara Armeni and Catherine Redgwell, "International Legal and Regulatory Issues of Climate Geoengineering Governance: Rethinking the Approach" (2015) Climate Geoengineering Governance Working Paper Series: 021. Available at: https://www.jura.uni-freiburg.de/de/institute/ioeffr2/downloads/lger/armeni-redgwell-international-legal-and-regulatory-issues-of-climate-geoengineering-governance.pdf.

Christopher M. Looney and Stephen K. Oney, "Seawater District Cooling and Lake Source District Cooling" (2007) 104:5 Energy Engineering 34-45.

Christopher Meisenkothen, "Subseabed Disposal of Nuclear Waste: An International Policy Perspective" (1999) 14:2 Connecticut Journal of international Law 631.

Christopher Pala, "Honolulu to Implement Cooling with Deep-Sea Water: System, to go On-line in 2012, is Designed to Reduce Costs and Greenhouse Gas Emissions" (2009) 44:1 Environmental Science & Technology 13-13.

Clair Gough, Ian Taylor, & Simon Shackley, "Burying Carbon Under the Sea: An Initial Exploration of Public Opinions" (2002) 13:6 Energy & Environment 883-900. Available at: https://www.jstor.org/stable/43734534?sid=primo.

Clifton E. Curtis, "Legality of Seabed Disposal of High-Level Radioactive Wastes Under the London Dumping Convention" (1985) 14:4 Ocean Development and International Law 383-415.

Curtis Deutsch, Daniel M. Sigman, John P. Dunne, Nicholas Gruber, & Jorge L. Sarmiento, "Spatial Coupling of Nitrogen Inputs and Losses in the Ocean" (2007) 445:11 *Nature* 163 -167.

D. Karl, R. Letelier, L. Tupas, J. Dore, J. Christian, & D. Hebel, "The Role of nitrogen Fixation in Biogeochemical Cycling in the Subtropical North Pacific Ocean" (1997) 388:6642 Nature 533-538.

Daniel P. Harrison, "Global Negative Emissions Capacity of Ocean Macronutrient Fertilization" (2017) 12:3 Environmental Research Letters 1-10.

David Archer, Bruce Buffett, & Victor Brovkin, "Ocean Methane Hydrates as a Slow Tipping Point in the Global Carbon Cycle" (2009) 106:49 Proceedings of the National Academy of Sciences 20596-20601.

David Freestone & Rosemary Rayfuse, "Ocean Iron Fertilization and International Law", (2008) 364 Marine Ecology Progress Series 227-234.

David Langlet, "Exporting CO2 for Sub-Seabed Storage: The Non-Effective Amendment to the London Dumping Protocol and its Implications" (2015) 30 International Journal of Marine and Coastal Law 395-417.

David P. Keller, Ellias Y. Feng, & Andreas Oschiles, “Potential Climate Engineering Effectiveness and Side Effects During a High Carbon Dioxide-Emission Scenario” (2014) 5:1 Nature 1-11.

Daniel P. Schrag, “Preparing to Capture Carbon” (2009) 315:5813 Science 812-813.

David S. Goldberg, Tao Takahashi, & Angela L. Slagle, “Carbon Dioxide Sequestration in Deep-Sea Basalt” (2008) 105:29 Proceedings of the National Academy of Sciences 9920-9925.

David S. Goldberg & Angela L. Slagle, “A Global Assessment of Deep-sea Basalt Sites for Carbon Sequestration” (2009) 1:1 Energy Procedia 3675-3682.

David S. Goldberg, Dennis V. Kent, & Paul E. Olsen, “Potential On-shore and Off-shore Reservoirs for CO2 Sequestration in Central Atlantic Magmatic Province Basalts” (2010) 107:4 Proceedings of the National Academy of Sciences 1327-1332.

David L. VanderZwaag, “Ocean Acidification and Geoengineering: Navigating Beyond the Law of the Sea” (2014) 47:1 Revue Belge de Droit International 137.

David W. Keith, “Geoengineering the Climate: History and Prospect” (2000) 25 Annual Review of Energy and the Environment 245- 284.

David W. Keith and James S. Rhodes, “Bury, Burn or Both: A Two-For-One Deal on Biomass Carbon and Energy” (2002) 54:3 Climate Change 375-377.

Dorte Krause-Jensen and Carlos M. Duarte “Substantial Role of Macroalgae in Marine Carbon Sequestration” (2016) 9:10 Nature Geoscience 737-742.

Douglas L. Karlen, Rattan Lal, Ronald F. Follett, John M. Kimble, Jerry L. Hatfield, John M. Miranowski, Cynthia A. Cambardella, Andrew Manale, Robert P. Anex, & Charles W. Rice, “Crop Residues: The Rest of the Story” (2000) 43:21 Environmental Science & Technology 8011-8015.

E. Baughman, A. Gnanadesikan, A. Degaetano, & A. Adcroft, “Investigation of the Surface and Circulation Impacts of Cloud-Brightening Geoengineering” (2012) 25:21 Journal of Climate 7527-7543.

Edda S. P. Aradottir, Ingvi Gunnarsson, Knud Dideriksen, Sigurdur R. Gislason, Bergur Sigfusson, Fidel Grandia, Eric Oelkers, Sandra O Snaebjornsdottir, “ CarbFix Final Report”. Available at: https://cordis.europa.eu/docs/results/283/283148/final1-carbfix-final-report-vff.pdf.

Elizabeth F. Quinby, “Regulating Geoengineering: Application of GMO Trade and Ocean Dumping Regulation” (2018) 51:1 Vanderbilt Journal of Transnational Law 211.

Elizabeth J. Cottier-Cook, Nidhi Nagabhatla, Yacine Badis, Marnie L. Campbell, Thierry Chopin, Weiping Dai, Jianguang Fang, Peimin He, Chad L. Hewitt, Gwang Hoon Kim, Yuanzi Huo, Zengjie Jiang, Gert Kema, Xinshu Li, Feng Liu, Hongmei Liu, Yuanyuan Liu, Qinqin Lu, Qijun Luo, Yuze Mao, Flower E. Msuya, Céline Rebours, Hui Shen, Grant D. Stentiford, Charles Yarish, Hailong Wu, Xinming Yang, Jihong Zhang, Yongdong Zhou, Claire M. M. Gachon, "Safeguarding the Future of the Global Seaweed Aquaculture Industry" (2016) United Nations University (INWEH) and Scottish Association for Marine Science Policy Brief 1-12, online: https://inweh.unu.edu/safeguarding-the-future-of-the-global-seaweed-aquaculture-industry/.

Elmar Kriegler, Gunnar Luderer, Nico Bauer, Lavinia Baumstark, Shinichiro Fujimori, Alexander Popp, Joeri Rogelj, Jessica Strefler, & Detlef P. van Vuuren, "Pathways limiting warming to 1.5°C: a tale of turning around in no time?" (2018) 376:2119 Philosophical Transactions of the Royal Society. Series A: Mathematical, Physical, and Engineering Science 20160457-20160457.

Eric E. Adams and Ken Caldeira, "Ocean Storage of CO2" (2008) 4:5 Elements 319-324.

Eric Adam, Makoto Akai, Guttorm Alendal, Lars Golmen, Peter Haugan, Howard Herzog, Stephen Masutani, Shigeo Murai, Gerard Nihous, Takashi Ohsumi, Yoshihisa Shirayama, Craig Smith, Eric Vetter, & C. S. Wong, "International Field Experiment on Ocean Carbon Sequestration" (2002) 36:21 Environmental Science & Technology 399, available at: https://doi-org.ezproxy.library.dal.ca/10.1021/es022442b.

Espen Moe & Jo-Kristian S Røttereng, "The post-carbon society: Rethinking the international governance of negative emissions" (2018) 44 Energy Research & Social Science 199.

Fabian Reith, David O. Keller, & Andreas Oschlies, “Revisiting Ocean Carbon Sequestration by Direct Injection: A Global Carbon Budget Perspective” (2016) 7:4 Earth System Dynamics 797-812.

Farhad Qanbari, Mehrand Pooladi-Darvish, S. Hamed Tabatabaie, & Gerami Shahab, “Storage of CO2 as Hydrate Beneath the Ocean Floor” (2011) 4 Energy Procedia 3997-4004.

Francesca Marubini and Brenda Thake, “Bicarbonate Addition Promotes Coral Growth” (1999) 44:3 Limnology and Oceanography 716-720.

Franz Xaver Perrez, “The Role of the United Nations Environment Assembly in Emerging Issues of International Law” (2020) 12:114 Sustainability 5680.

Fumio Inagaki, Marcel M. M. Kuypers, Urumu Tsunogai, Jun-ichiro Ishibashi, Ko-ichi Nakamura, Tina Treude, Satoru Ohkubo, Miwako Nakaseama, Kaul Gena, Hitoshi Chiba, Hisako Hirayama, Takuro Nunoura, Ken Takai, Bo B. Jorgensen, Koki Horikoshi, & Antje Boetius, “Microbial Community in a Sediment-Hosted CO2 Lake of the Southern Okinawa Through Hydrothermal System” (2006) 103:38 Proceedings of the National Academy of Sciences 14164-14169.

Gail Whiteman, Chris Hope, & Peter Wadhams, “Methane Released by Melting Permafrost Will have Global Impacts that Must be Better modelled” (2013) 499 Nature 401-403.

Geir Ersland, Jarle Husebo, Arne Graue, & Bjorn Kvamme, “Transport and Storage of CO2 in Natural Gas Hydrate Reservoirs” (2009) 1:1 Energy Procedia 3477-3484.

Geir Ottersen, Knut Yngve Borsheim, Lars Arneborg, Marie Maar, Vibe Schourup-Kristensen, Elin Almroth Rosell, Magnus Hieronymus, *Observed and Expected Future Impacts of Climate Change on Marine Environment and Ecosystems in the Nordic Region* (Havforskningsinstituttet, 2023). Available at: https://imr.brage.unit.no/imr-xmlui/handle/11250/3057234.

Grant Wilson, “Murky Waters: Ambiguous International Law for Ocean Fertilization and other Geoengineering” (2014) 49:1-3 Texas International Law Journal 507.

Greg H. Rau and Jim R. Baird, “Negative-CO2-Emissions Ocean Thermal Energy” (2018) 95 Renewable and Sustainable Energy Reviews 265-272.

Gunther Handl, “National Uses of Transboundary Air Resources: The International Entitlement Issue Reconsidered” (1986) 26:3 National Resources Journal 405-467.

Gunther Handl, “The Principle of Equitable Use as Applied to Internationally Shared Natural Resources: Its Role in Resolving Potential International Disputes Over Transfrontier Pollution” (1978) 14:1 Revue Belge de Droit International/Belgian Review of International Law 40.

H. Koide, Y. Shindo, Y. Tazaki, M. Iijima, K. Ito, N. Kimura, & K. Omata, "Deep Sub-Seabed Disposal of CO2: The Most Protective Storage" (1997) 38:1 Energy Conversion and Management s253-s258.

H. Koide, M. Takahashi, Y. Shindo, Y. Tazaki, M. Iijima, K. Ito, N. Kimura, & K. Omata, "Hydrate Formation in Sediments in the Sub-Seabed Disposal of CO2" (1997) 22:2-3 Energy 279-283.

Hans Aksel Haugen and Lars Ingolf Elde, "CO2 Capture and Disposal: The Realism of Large Scale Scenarios" (1996) 37:6-8 Energy Conversion and Management 1061 -1066. Available at: https://doi.org/10.1016/0196-8904(95)00298-7.

Harold Ginzky & Robyn Frost, "Marine Geo-Engineering: Legally Binding Regulation under the London Protocol" (2014) 8:2 Carbon & Climate Law Review 82.

Helen Knight, "Oceans of Power: The Resurrection of Ocean Thermal" (2014) 221:2958 New Scientist 48-51.

Hubertus Welsch, "The London Dumping Convention and Sub-Seabed Disposal of Radioactive Waste" (1985) 38 German Yearbook of International Law 322.

IK Kyo Chung, John Beardall, Smita Mehta, Dinabandhu Sahoo, & Slobodanka Stojkovic, "Using Marine Macroalgae for Carbon Sequestration: A Critical Appraisal" (2011) 23:5 Journal of Applied Phycology 877-886.

IK Kyo Chung, Jung Hyun Oak, Jin Ae Lee, Jong Ahm Shin, Jong Gyu Kim, & Kwang-Seok Park, "Installing Kelp Forests/Seaweeds Beds for mitigation and Adaptation Against Global Warming: Korean Project Overview" (2013) 70:5 ICES Journal of Marine Science 1038-1044.

J. B. C. Jackson and K. G. Johnson, "Life in the Last Few Millions Years" (2002) 26:4 Paleobiology 221-235.

J. S. Levine, J. M. Matter, D. Goldberg, A. Cook, & K. S. Lackner, "Gravitational Trapping of Carbon Dioxide in Deep Sea Sediments: Permeability, Buoyancy, and Geomechanical Analysis" (2007) 34:24 Geophysical Research Letters L24703-n/a.

J. H. Martin, S. E. Fitzwater, & R. M. Gordon, "Iron Deficiency Limits Phytoplankton Growth in Antarctic Waters" (1990) 4 *Global Biogeochemistry Cycle* 5-12.

J. R. G. Evans, E. P. J. Stride, M. J. Edirisinghe, D. J. Andrews, & R. R. Simons, "Can Oceanic Foams Limit Global Warming" (2010) 42:2 Climate Research 155-160.

James C. Orr, Ernst Maier-Reimer, Uwe Mikolajewicz, Patrick Monfray, Jorge L. Sarmiento, J. R. Toggweiler, Nicholas K. Taylor, Jonathan Palmer, Nicolas Gruber, Christopher L. Sabine, Corinne Le Quere, Robert M. Key, & Jacqueline Boutin, "Estimates of Anthropogenic Carbon Uptake from Four Three-Dimensional Global Ocean Models" (2001) 15:1.

James E. Lovelock and Chris Rapley, "Ocean Pipes Could Help the Earth to Cure Itself" (2007) 449:7161 Nature 403-403.

James K. B. Bishop, Todd J. Wood, Russ E. Davis, & Jeffrey T. Sherman, "Robotics Observations of Enhanced Carbon Biomass and Export at 55°S During SOFeX". Available at: https://www.science.org/doi/10.1126/science.1087717.

James P. Barry, Kurt R. Buck, Chris F. Lovera, Linda Kuhnz, Patrick J. Whaling, Edward T. Peltzer, Peter Walz, & Peter G. Brewer, "Effects of Direct Ocean CO2 Injection on Deep-Sea Meiofauna" (2004) 60:4 Journal of Oceanography 759-766.

James Waczewski, "Legal, Political and Scientific Response to Ocean Dumping and Sub-seabed Disposal of Nuclear Waste" (1997) 7 Journal of transactional Law and Policy 97-118.

James K. Reaser, Rafe Pomerance, & Peter O. Thomas, "Coral Bleaching and Global Climate Change: Scientific Findings and Policy Recommendations" (2000) 14:5 Conservation Biology 1500-1511.

Jan McDonald, Jeffrey McGee, Kerryn Brent, & Wil Burns, "Governing Geoengineering Research for the Great Barrier Reef" (2019) 19:7 Climate Policy 801-811.

Jeffrey McGee, Kerryn Brent, & Wil Burns, "Geoengineering the Oceans: An Emerging Frontier in International Climate Change Governance" (2018) 10:1 *Australian Journal of Maritime & Ocean Affairs* 67 -80.

Jens Hartmann, Joshua A. West, Phil Renforth, Peter Kohler, Christina L. De La Rocha, Dieter A. Wolf-Gladrow, Hans H. Durr, & Jurgen Scheffran, "Enhanced Chemical Weathering as a Geoengineering Strategy to Reduce Atmospheric Carbon Dioxide, Supply Nutrients, and Mitigate Ocean Acidification" (2013) 51:2 Reviews of Geophysics 113-149.

Jim Giles, "Norway Sinks Ocean Carbon Study" (2002) 419:6902 Nature (London) 6-6. Available at: https://doi.org/10.1038/419006b.

Joeri Rogelj, Michel Den Elzen, Niklas Hohne, Taryn Fransen, Hanna Fekete, Harald Winker, Roberto Schaeffer, Fu Sha, Keywan Riahi, & Malter Meinshausen, "Paris Agreement climate proposals need a boost to keep warming well below 2°C" (2017) 534 Nature 631.

John J. Cullen, "Hypotheses to Explain High-Nutrient Conditions in the Open Area" (1991) 36:6 *Limnology Oceanography* 1578-1599.

John Cullen, "Status of the Iron Hypothesis After the Open-Ocean Enrichment Experiment" (1995) 40:7 Limnology and Oceanography 1336-1343.

John Latham, "Control of Global Warming" (1990) 347 Nature 339-340.

Jorge L. Sarmiento and Gruber, "Sinks for Anthropogenic Carbon" (2002) 55:8 Physics Today 30-36. Available at: https://doi.org/10.1063/1.1510279.

John Latham, Philip Rasch, Chih-Chieh Chen, laura Kettles, Alan Gadian, Andrew Gettelman, Hugh Morrison, Keith Bower, & Tom Choularton, "Global Temperature Stabilization via Controlled Albedo Enhancement of Low-Level Maritime Clouds" (2008) 366:1882 Mathematical, Physical, and Engineering Sciences 2969-3987.

John Latham, Keith Bower, Tom Choularton, Hugh Coe, Paul Connolly, Gary Cooper, Tim Gary, Jack Foster, Alan Gadian, Lee Galbraith, Hector Lacovides, David Johnston, Brian Launder, Brian Leslie, John Meyer, Armand Neukermans, Bob Ormond, Ben Parkes, Philip Rasch, John Rush, Stephen Salter, Tom Stevenson, Hailong Wang, Qin Wang, & Rob Wood, "Marine Cloud Brightening" (2012) 370:1974 Mathematical, Physical, and Engineering Sciences 4217-4262.

John Latham, Philip Rasch, Chih-Chieh Chen, Laura Kettles, Alan Gadian, Andrew Gettleman, Hugh Morrison, Keith Bower, & Tom Choularton, "Marine Cloud Brightening: Regional Applications" (2014) 372:2031 Mathematical, Physical, and Engineering Sciences 20140053.

John W. Pohlman, Jens Greinert, Carolyn Ruppel, Anna Silyakova, Lisa Vielstadte, Michel Casso, Jurgen Mienert, & Stefan Bunz, "Enhanced CO2 Uptake at a Shallow Arctic Ocean Seep

Field Overwhelms the Positive Warming Potential of Emitted Methane" (2017) 114:21 Proceedings of the National Academy of Sciences 5355-5360.

Jonathan I. Charney, "The Marine Environment and the 1982 United Nations Convention on the Law of the Sea" (1994) 28:4 The International Lawyer 879-901.

Jonathan. L. Hafetz, "Fostering Protection of the Marine Environment and Economic Development: Article 121(3) of the Third Law of the Sea Convention," (2000) 15:3 American University International Law Review 583.

Joshuah K. Stolaroff, Subarna Bhattacharyya, Clara A. Smith, William L. Bourcier, Philip J. Cameron-Smith, & Roger D. Aines, "Review of Methane Mitigation Technologies with Application to Rapid Release of Methane from the Arctic" (2012) 46:12 Environmental Science & Technology 6455-6469. Available at: https://pubs.acs.org/doi/10.1021/es204686w.

Juerg M. Matter, Martin Stute, Sandra O. Snaebjornsdottir, Eric H. Oelkers, Sigurdur R. Gislason, Edda S. Aradottir, Bergur Sigfusson, Ingvi Gunnarsson, Holmfridur Sigurdarfottir, Einar Gunnlaugsson, Gudni Axelsson, Helgi A. Alfredsson, Domenik Wolff-Boenisch, Kiflom Mesfin, Diana Fernandez de la Reguera Taya, Jennifer Hall, Knud Dideriksen, & Wallace S. Broecker, "Rapid Carbon Mineralization for Permanent Disposal of Anthropogenic Carbon Dioxide Emissions" (2016) 352:6291 Science 1312-1314.

Julia A. Crook, Lawrence S. Jackson, & Piers M. Forster, "Can Increasing Albedo of. Existing Ship Wakes Reduce Climate Change?" (2016) 121:4 Journal of Geophysical Research: Atmospheres 1549-1558.

Jun Kita and Takashi Ohsumi, "Perspectives on Biological Research for CO2 Ocean Sequestration" (2004) 60:4 Journal of Oceanography 695-703.

Jurg M. Matter and Peter B. Kelemen, "Permanent Storage of Carbon Dioxide in Geological Reservoirs by Mineral Carbonation" (2009) 2:17 Nature Geoscience 837-841.

K. E. Kohfeld and S. P. Harrison, "How Well Can We Simulate Past Climates? Evaluating the Models Using Global Palaeoenvironmental Datasets" (2000) 19:1 Quaternary Science Reviews 321-346.

K. Siv Lauvset, Jerry Tjiputra, & Helene Muri, "Climate Engineering and the Ocean: Effects on Biogeochemistry and Primary Production" (2017) 14:24 Biogeochemistry 5675-5691.

Kara Lavender Law and Richard C. Thompson, "Microplastics in the Sea" (2014) 345:6193 Science 144-145.

Karen N. Scott, "Engineering the 'Mis-Anthropocene': International Law, Ethics and Geoengineering" (2015) 29:1 Ocean Yearbook 61-84.

Karen N. Scott, "International Law in the Anthropocene: Responding to the geoengineering Challenge" (2012) 34:2 Michigan Journal International 309.

Karen N. Scott, "Regulating Ocean Fertilization under International Law: The Risks" (2013) 2013:2 CCLR 108.

Karen N. Scott, "The Day After Tomorrow: Ocean CO2 Sequestration and the Future of Climate Change" (2005) 18:1 Georgetown International Environmental Law Review 57.

Klaus S. Lackner, Christopher H. Wendt, Darryl P. Butt, Edward L. Joyce, & David H. Sharp, "Carbon Dioxide Disposal in Carbonate Minerals" (1995) 20:11 Energy 1153-1170.

Kurt Zenz House, Daniel P. Schrag, Charles F. Harvey, & Klaus S. Lackner, "Permanent Carbon Dioxide Storage in Deep-Sea Sediments" (2006) 103:33 Proceedings of the national Academy of Sciences 12291-12295.

L. Field, D. Ivanova, S. Bhattacharyya, V. Mlaker, A. Sholtz, R. Decca, A. Manzara, D. Johnson, E. Christodoulou, P. Walter, & K. Katuri, "Increasing Arctic Sea Ice Albedo Using Localized Reversible Geoengineering" (2018) 6:6 Earth's Future 882-901.

Lenore Newman and Yuill Herbert, "The Use of Deep Water Cooling Systems: Two Canadian Examples" (2009) 34:3 Renewable Energy 727-730.

Lester Kwiatkowski, Katharine L. Ricke, & Ken Caldeira, “Atmospheric Consequences of Disruption of the Ocean Thermocline” (2015) 10:3 Environmental Research Letters 34016.

Liliana B. Andonova and Ronald B. Mitchell, “The (1) Rescaling of Global Environmental Politics” (2010) 35 Annual Review of Environmental Resources 255-282.

Louise de La Fayette, “The OSPAR Convention Comes into Force: Continuity and Progress” (1999) 14:2 the International Journal of Marine and Coastal Law 247-297.

Lyla L. Taylor, Joe Quirk, Rachel M. S. Thorley, Pushker A. Kharecha, James Hansen, Andy Ridgwell, Mark R. Lomas, Steve A. Banwart, & David J. Beerling, “Enhanced Weathering Strategies for Stabilizing Climate and Averting Ocean Acidification” (2016) 6:4 Nature Climate Change 402-406.

Lynn Wagner, “The United Nations Environment Assembly’s Role as a Governance Architect” CE Think Tank Newswire (28 February 2022). Available on: https://www.proquest.com/docview/2634789297?pq-origsite=primo&parentSessionId=TBODHjVZa9DqWXk01rcVT0SXvKV2HLyViRYHm8J4K0Q%3D.

Maja Vinde Folkerson, Christopher M. Fleming, & Syezlin Hasan, “The Economic Value of the Deep Sea: A Systematic Review and Meta-Analysis” (2018) 94 Marine Policy 71-80.

Maria Creary, "Impacts of Climate Change on Coral Reefs and the Marine Environment" (2013) 50:1 UN Chronicle 24-27.

Marianne Mackintosh, "The Development of International Law in Relation to the Dumping and Disposal of Radioactive Waste at Sea" (2003) 14 Journal of International Maritime Law 354.

Mark E. Capron, Jim R. Stewart, & Kerry R. Rowe, "Secure Seafloor Container CO2 Storage" (2013) Oceans 1-8.

Mark G. Lawrence, Stefan Schafer, Helene Muri, Vivian Scott, Andreas Oschlies, Noami E. Vaughan, Oliver Boucher, Hauke Schmidt, Jim Haywood, & Jurgen Scheffran, "Evaluating climate geoengineering proposals in the context of the Paris Agreement temperature goals" (2018) 9:1 Nature Communications 1-19.

Martin H. Belsk, "The Ecosystem Model Mandate for a Comprehensive United States Ocean Policy and Law of the Sea" (1989) 26:3 The San Diego Law Review 417.

Mary W. Silver, Sibel Bargu, Susan L. Coale, Claudia R. Benitez-Nelson, Ana C. Garcia, Kathryn J. Roberts, Emily Sekula-Wood, Kenneth W. Bruland, Kenneth H. Coale, & M. M. Morel, "Toxic Diatoms and Domoic Acid in Natural and Iron Enriched Waters of the Oceanic Pacific" (2010) 107:48 *Proceedings of the National Academy of Sciences* 20762 – 20767.

Meinhard Doelle, “Climate Change and the Use of the Dispute Settlement Regime of the Law of the Sea Convention” (2006) 37:3-4 Ocean Development and International Law 319-337.

Melissa Eick, “A Navigational System for Uncharted Waters: The London Convention and London Protocol’s Assessment Framework on Ocean Fertilization” (2010) 46 Tulsa L. Rev 351.

Miranda Boettcher & Rakhyun E. Kim, “Arguments and Architectures: Discursive and Institutional Structures Shaping Global Climate Engineering Governance” (2022) 128 Environmental Science & Policy 121-131.

Moira L. McConnell & Edgar Gold, “The Modern Law of the Sea: Framework for the Protection and Preservation of the Marine Environment?” (1991): 83 Case Western Reserve Journal of International Law 83-105.

Naomi E. Vaughan & Timothy M. Lenton, "A Review of Climate Geoengineering Proposals” (2011) 190:3-4 Climate Change 745-790.

Natalia Shakhova, Igor Semiletov, Anatoly Salyuk, Vladimir Yusupov, Denis Kosmach, & Orjan Gustafsson, “Extensive Methane Venting to the Atmosphere from Sediments of the East Siberian Arctic Shelf” (2010) 327:5970 Science 1246-1250.

Naval Goel, “In Situ Methane Hydrate Dissociation with Carbon Dioxide Sequestration: Current Knowledge and Issues” (2006) 15:3-4 Journal of Petroleum Science and Engineering 169-184.

Nick J. Hardman-Mountford, Luca Polimene, Takafumi Hirata, Robert J. W. Brewin, J. W. Robert, Jim Aiken, "Impacts of Light Shading and nutrient Enrichment Geoengineering Approaches on the Productivity of a Stratified, Oligotrophic Ocean Ecosystem" (2013) 10:89 Journal of the Royal Society Interface 20130701-20130701.

Olivia Serdeczny, Sophie Adams, Florent Baarsch, Dim Coumou, Alexander Robinson, William Hare, Michiel Schaeffer, Mahe Perrette, & Julia Reinhardt, "Climate Change Impacts in Sub-Saharan Africa: From Physical Changes to their Social Repercussions" (2017) 17:6 Regional Environmental Change 1585-1600.

P. K. Quinn and T. S. Bates, "The Case Against Climate Regulation via Oceanic Phytoplankton Sulphur Emissions" (2011) 480 Nature 51-56.

P. M. Holligan, E. Fernandez, J. Aiken, W. M. Balch, P. Boyd, P. H. Burkill, M. Finch, S. B. Groom, G. Malin, & K. Muller, "A Biogeochemical Study of the Coccolithophore Emiliania Huxleyi, in the North Atlantic" (1993) 7:4 Global Biogeochemical Cycles 879-900.

P. W. Boyd, T. Jickells, C. S. Law, S. Blain, E. A. Boyle, K. O. Buesseler, K. H. Coale, J. J. Cullen, H. J. W. de Baar, M. Follows, M. Harvey, C. Lancelot, M. Levasseur, N. P. J. Owens, R. Pollard, R. B. Rivkin, J. Sarmiento, V. Schoemann, V. Smetacek, S. Takeda, A. Tsuda, S. Turner, & A. J. Watson, "Mesoscale Iron Enrichment Experiments 1992-2005: Synthesis and Future Directions" (2007) 315:5812 *Science* at 612-617.

P. Williamson, R. T. Watson, G. Mace, P. Artaxo, R. Bodle, V. Galaz, A. Parker, D. Santillo, C. Vivian, D. Cooper, J. Webbe, A. Cung, and E. Woods, *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters* (2016) Technical Series No. 66, 152, Secretariat of the Convention on Biological Diversity. Available at: https://www.cbd.int/doc/publications/cbd-ts-66-en.pdf.

Patricia M. Gilbert, Roxane Maranger, Daniel J. Sobota, Lex Bouwman, "The Haber Bosch-Harmful Algal Bloom (HB-HAB) Link" (2014) 9:10 Environmental Research Letters 1 -13.

Paul J. Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" (2006) 77:3-4 Climate Change 211-220.

Peter G. Brewer, Edward T. Peltzer, Peter M. Walz, Elizabeth K. Coward, Laura A. Stern, Stephen H. Kirby, & John Pinkston, "Deep-Sea Field Test of the CH4 Hydrate to CO2 Hydrate Spontaneous Conversion Hypothesis" (2014) 28:11 Energy & Fuels 7061-7069.

Peter B. McGrail, Todd H. Schaef, Anita M. Ho, Yi-Ju Chien, James J. Dooley, & Casie L Davidson, "Potential for Carbon Dioxide Sequestration in Flood Basalts" (2006) 111: B12 Journal of Geophysical Research B12201-n/a.

Peter U. Clark, Jeremy D. Shakun, Shaun A. Marcott, Alan C. Mix, Michael Eby, Scott Kulp, Anders Levermann, Glenn A. Milne, Patrik L. Pfister, Benjamin D. Santer, Daniel P. Schrag, Susan Solomo n, Thomas F. Stocker, Benjamin H. Strauss, Andrew J. Weaver, Ricarda Winkelmann, David Archer, Edouard Bard, Aaron Goldner, Kurt Lambeck, Raymond T. Pierrehumbert, & Gian-Kasper Plattner, "Consequences of Twenty-First Century Policy for Multi-Millennial Climate and Sea-Level Change" (2016) 6 Nature Climate Change 360.

Phil Renforth and Gideon Henderson, "Accessing Ocean Alkalinity for Carbon Sequestration: Ocean Alkalinity for C Sequestration" (2017) 55:3 Reviews of Geophysics 636-674.

Phillip Williamson, Douglas W. R. Wallace, Cliff S. Law, Phillip W. Boyd, Yves Collos, Peter Croot, Ken Denman, Ulf Riebesell, Shigenobu Takeda, & Chris Vivian, "Ocean Fertilization for Geoengineering: A Review of Effectiveness, Environmental Impacts and Emerging Governance" (2012) 90:6 Process Safety and Environmental Protection 475-488, Available at: https://doi.org/10.1016/j.psep.2012.10.007.

Philomene A. Verlaan, "Environmental Activities that Intentionally Perturb the Marine Environment: Implications for the Marine Environmental Protection and Marine Scientific Research Provisions of the 1982 United Nations Convention on the Law of the Sea" (2007) 31:2 Marine Policy 210-216.

Ponnivalavan Babu, She Hern Bryan Yang, Dasgupta Somik, & Praveen Linga, "Methane Production from Natural Gas Hydrates via Carbon Dioxide Fixation" (2014) 61 Energy Procedia 1776-1779.

R. Pereira and C. Yarish, "Mass Production of Marine Macroalgae" (2008) 3 Encyclopedia of Ecology 2236-2247.

Rachel Zajacek, "The Development of Measures to Protect the Marine Environment from Land-Based Pollution: The Effectiveness of the Great Barrier Reef Marine Park Authority in Managing the Effects of Tourism on the Marine Environment" (1996) 3 James Cook University Law Review 64-92.

Rebecca Albright, Lilian Caldeira, Jessica Hosfelt, Lester Kwaiatkowski, Jana K. Maclaren, Benjamin M. Mason, Yana Nebuchina, Aaron Ninokawa, Julia Pongratz, Katharine L. Ricke, Tanya Rivlin, Kenneth Schneider, Marine Sesboue, & Kathryn Shamberger, Jacob Silverman, Knnedy Wolfe, Kai Zhu, & Ken Caldeira, "Reversal of Ocean Acidification Enhances Net Coral Reef Calcification" (2016) 531:7594 Nature 362-365.

Richard G. Keil, Jonathan M. Nuwer, & Stuart E. Strand, "Burial of Agricultural Byproducts in the Deep Sea as a Form of Carbon Sequestration: A Preliminary Experiment" (2010) 122:1 Marine Chemistry 91-95.

Rob Bellamy, "Incentivize negative emissions responsibly" (2018) 3 Nature Energy 532-534.

Robert A. Mertzger & Gregory Benford, "Sequestering of Atmospheric Carbon Through Permanent Disposal of Crop Residue" (2001) 49:1-2 Climate Change 11-19.

Robert A. Metzger, Gregory Benford, Martin I. Hoffert, David W. Keith, & James S. Rhodes, "To Bury or to Burn: Optimum Use of Crop Residues to Reduce Atmospheric CO2" (2002) 54:3 Climate Change 369-374.

Robert J. Charlson, J. E. Lovelock, M. O. Andreae, & S. G. Warren, "Oceanic Phytoplankton, Atmospheric Sulphur, Cloud Albedo and Climate" (1987) 326 Nature 655-661.

Robert J. Diaz and Rutger Rosenberg, "Spreading Dead Zones and Consequences for Marine Ecosystems" (2008) 321: 5891 *Science* 926-929.

Roberta C. Hamme, Peter W. Webley, William R. Crawford, Frank A. Whitney, Michael D. Degrandpre, Steven R. Emerson, Charles C. Eriksen, Karina E. Giesbrecht, Jim F. R. Gower, Maria T Kavanaugh, M. Angelica Pena, Christopher L. Sabine, Sonia D. Batten, Laurence A. Coogan, Damian S. Grundle, & Deirdre Lockwood, "Volcanic Ash Fuel Anomalous Plankton Bloom in Subarctic Northeast Pacific" (2010) 31:19 Geophysical Research Letters 1-5.

Robin Warner, "Marine Snowstorms: Assessing the Environmental Risks of Ocean Fertilization" (2009) 2009:4 Carbon & Climate Law Review 426.

Rod Fujita, Alexander C. Markham, Julio E. Diaz Diaz, Julia Rosa Martinez Garcia, Courtney Scarborough, Patrick Greenfield, Peter Black, & Stacy E. Aguilera, "Revisiting Ocean Thermal Energy Conversion" (2012) 36:2 Marine Policy 463-465.

Rosalia Trias, Benedicte Menez, Paul Le Campion, Yvan Zivanovic, Lena Lecourt, Aurelien Lecoeuvre, Philippe Schmitt-Kopplin, Jenny Uhl, Sigurour R. Gislason, Helgi A. Alfredsson, Kiflom G. Mesfin, Sandra O. Snaebjornsdottir, Edda S. Aradottir, Ingvi Gunnarsson, Juerg M. Matter, Martin Stute, Eric H. Oelkers, & Emmanuelle Gerard, "High Reactivity of Deep Biota Under Anthropogenic CO2 Injection into Basalt" (2017) 8:1 Nature Communications 1 -14.

Russell Seitz, "Bright Water: Hydrosols, Water Conservation and Climate Change" (2011) 105:3-5 Climate Change 365-381.

S. Zhou and P. C. Flynn, "Geoengineering Downwelling Ocean Currents: A Cost Assessment" (2005) 71:1-2 Climate change 203-220.

Sabine Fuss, William F. Lamb, Max W. Callaghan, Jerome Hilaire, Felix Creutzig, Thorben Amann, Tim Beringer, Wagner de Oliveira Garcia, Jens Hartmann, Tarun Khanna, Gunnar Luderer, Gregory F. Nemet, Joeri Rogelj, Pete Smith, Jose Luis Vincente Vincent, Jennifer Wilcox, Dominguez del Mar Zamora, & Jan C. Minx, "Negative emissions—Part 2: Costs, potentials and side effects" (2018) 13:6 Environmental Research Letters 63002.

Sarah E. Hamill, "Review of Legal History" (2019) 28:4 Social and Legal Studies 538-559.

Sherry P. Broder and Marcus Haward, "The International Legal Regimes Governing Ocean Iron Fertilization" (2013) Regions, Institutions, and Law of the Sea: Studies in Oceans Governance 185-220.

Shuo Liu, Lige Zhao, Canbo Xiao, Wei Fan, Yong Cai, Yiwen Pan, & Ying Chen, "Review of Artificial Downwelling for Mitigating Hypoxia in Coastal Waters" (2020) 12:10 Water (Basel) 1 – 18.

Shylesh Muralidharan, "Assessment of Ocean Thermal Energy Conversion", (2012) MSc Thesis, Massachusetts Institute of Technology, online: http://dspace.mit.edu/handle/1721.1/76927#files-area.

Sikina Jinnah& Simon Nicholson, "The Hidden Politics of Climate Engineering" (2019) 12:11 Nature 876-879.

Sofia Frantzi, "What Determines the Institutional Performance of Environmental Regimes? A Case Study of the Mediterranean Action Plan" (2008) 32:4 Marine Policy 618-629.

Steve Goldthorpe, "Potential for Very Deep Ocean Storage of CO2 Without Ocean Acidification: A Discussion Paper" (2017) 114 Energy Procedia 5417-5429.

Stefano Caserini, Giovanni Dolci, Arianna Azzellino, Caterina Lanfredi, Lucia Rigamonti, Beatriz Barreto, & Mario Grosso, "Evaluation of a New Technology for Carbon Dioxide Submarine Storage in Glass Capsules" (2017) 60 International Journal of Greenhouse Gas Control 140-155.

Stephen Salter, Graham Sortino, & John Latham, "Sea-going Hardware for the Cloud Albedo Method of Reversing Global Warming" (2008) 366:1882 Mathematical, Physical, and Engineering Sciences 3989-4000.

Stephen H. Salter, "Can We Capture Methane from the Artic Seabed?" (16 October 2011), online: http://arctic-news.blogspot.com/p/methane-capture.html.

Steven J. Desch, Nathan Smith, Christopher Groppi, Perry Vargas, Rebecca Jackson, Anusha Kalyaan, Peter Nguyen, Luke Probst, Mark E. Rubin, Heather Singleton, Alexander Spacek, Amanda Truitt, Pye Pye Zaw, Hilairy E. Hartnett, "Arctic Ice Management" (2016) 5:1 Earth's Future 107-127.

Stuart E. Strand & Gregory Benford, "Ocean Sequestration of Crop Residue Carbon: Recycling Fossil Fuel Carbon Back to Deep Sediments" (2009) 43:4 Environmental Science & Technology 1000-1007.

The Royal Society, Geoengineering the Climate: Science, Governance and Uncertainty (London: The Royal Society, 2019). Available at: https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2009/8693.pdf.

The Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (Policy Document) (London: Royal Society, 2009), Available at: https://royalsociety.org/~/media/royal_society_content/policy/publications/2009/8693.pdf.

The Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty (*London: Royal Society, 2009*)*. Available at: https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2009/8693.pdf.

Tim Dixon, Andy Greaves, Oyvind Christophersen, Chris Vivian, & Jolyon Thomson, "International Marine Regulation of CO2 Geological Storage Developments and Implications of London and OSPAR" (2009) 1 Energy Procedia 4503-4510.

V. S. Mani, "Ocean Dumping of Radioactive Wastes: Law and Politics" (1984) 24:2 Indian Journal of International Law 224-244.

Virginia Gewin, "Ocean Carbon Study to Quit Hawaii" (2002) 417:6892 Nature (London) 888-888. Available at: https://doi.org/10.1038/417888b.

W. Seifritz, "CO2 Disposal by Means of Silicate" (1990) 345:6275 Nature 486-486.

Xavier Mari, Uta Passow, Christophe Migon, Adrian Burd, & Louis Legendre, “Transport Exopolymer Particles: Effects on Carbon Cycling in the Ocean” (2017) 151 Progress in Oceanography 13-37.

Y. C. Beaudoin, R. Boswell, S. R. Dallimore, & W. Waite, “Frozen Heat: A UNEP Global Outlook on Methane Gas Hydrates” (2014) United Nations Environment Programme, GRID-Arendal. Available at: https://www.netl.doe.gov/sites/default/files/netl-file/gas-hydrate-global-assessment-executive-summary%5B1%5D.pdf;

Yihua Teng and Dongxiao Zhang, “Long-Term Viability of Carbon Sequestration in Deep-Sea Sediments” (2018) 4:7 Sciences Advances eaao6588-eaao6588.

Youngjune Park, Do-Youn Kim, Jong-Won Lee, Dae-Gee Huh, Keun-Pil Park, Jaehyoung Lee, & Huen Lee, “Sequestering Carbon Dioxide into Complex Structures of Naturally Occurring Gas Hydrates” (2006) 103:34 Proceedings of the National Academy of Sciences 12690-12694.