Enhancement of Marine Sinks in International Climate Policy

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Abstract

It is increasingly likely that the world will fail to meet the target of "well below 2 degrees Celsius" of warming put forth by the Paris Agreement without a swift and enormous change in policy and perspective. It is also increasingly evident that the ocean's ability to adapt to and mitigate a high carbon world is weakening. Policy options that remove carbon dioxide from the atmosphere, as well as increase ocean resilience should be better researched and included in the climate discussion. Enhancement of coastal and marine systems is an attractive set of options for removing atmospheric carbon dioxide and reducing ocean vulnerability. Management options in this sphere include conventional approaches, such as increasing protected marine areas of ecological and carbon importance, and unconventional approaches, such as ocean-based carbon dioxide removal (CDR). However, international governance bodies, like the United Nations Framework Convention on Climate Change (UNFCCC), have failed to include a discussion of how to regulate and govern marine CDR approaches. This research recommends that the UNFCCC further emphasize and better integrate marine sinks in greenhouse gas accounting and the Paris Rulebook, in addition to creating a working group to evaluate CDR projects and integrate existing environmental principles. This will allow better inclusion of marine sinks across scales, with a uniform and measurable process.

Introduction

Global climate change presents the largest environmental, social, and economic challenge in modern human history. In light of the possibly devastating consequences of a warming world, recent decades have seen unprecedented global cooperation. However, this impressive international effort still fails to catalyze the transformation needed to stay within the global temperature target of well under two degrees Celsius, as set by the Paris Agreement.[1] Recent reports show that to limit warming to 1.5°C, global greenhouse gas emissions must peak by 2020.[2] However, "locked-in" warming may already be up to 1.3°C, suggesting we may surpass this target much sooner than previously thought due to our failure to reduce emissions.[3] While the ideal scenario remains prevention of greenhouse gas or carbon emissions, it is increasingly likely that the use of Negative Emissions Technologies (NETs) will be required in order to avoid dangerous anthropogenic climate change.[4]

Inexorably linked to the climate crisis are our oceans, the earth's water storehouse, climate driver, and largest carbon sink. Even if the global temperature increase is kept to two degrees Celsius, virtually all tropical coral reefs are projected to be at risk of severe degradation from this increased warming.[5] Oceans have mitigated much of the climate change felt on land, absorbing 26 percent of anthropogenic carbon dioxide (CO_2) emissions, as well as over 90 percent of the additional energy stored in the climate system.[6] However, this absorption is beginning to slow as waters become warmer, and there are many consequences to the increase in carbon. One such consequence is emissions-driven ocean acidification, or "the other CO_2 problem." This has devastating effects on a variety of marine life, particularly organisms with calcium carbonate shells, which the acidity dissolves.[7] Oceans are now approximately 30 percent more acidic on average than they were in the 1750s, equivalent to a 0.1 pH unit reduction with an additional decrease of 0.3-0.4 pH expected by 2100.[8] Yet, while there have been scientific studies on the importance of marine services and marine sinks—or ocean-based carbon reservoirs—for climate regulation processes, there has been little discussion on the inclusion of marine systems, such as coastal wetlands, kelp forests, or coral reefs, within relevant climate frameworks and governance.

Innovative climate solutions that foster ocean health and climate change mitigation should be better researched in the natural sciences and, crucially, better discussed in international policy. The important role of marine ecosystems in climate adaptation and mitigation highlights the need to conserve and manage these resources for resilience and ecosystem health. In addition, natural ocean sinks can be enhanced, and natural sequestration processes can be accelerated in order to address atmospheric CO_2 and ocean acidification. Enhancement of marine systems emerges as an attractive approach to climate change and marine conservation, and thus should be better integrated into international climate governance.

[1] UNFCC, "The Paris Agreement," 2015.
[2] *The Emissions Gap Report*, 9.
[3] Mauritsen and Pincus, "Committed Warming Inferred from Observations," 1.
[4] Craik and Burns, *Climate Engineering under the Paris Agreement*, 5.
[5] Schleussner et al., "Differential climate impacts," 327-351.
[6] *Climate Change 2014: Synthesis Report,* 40.
[7] Ibid., 67.
[8] Orr et al., "Anthropogenic Ocean Acidification," 3.

Background: Carbon Dioxide Removal

Climate negotiations have historically focused on mitigation, or the reduction of greenhouse gas emissions, and more recently adaptation, or the response to existing climate change to limit vulnerability, but some scholars and policy makers are shifting attention toward a group of approaches that fall broadly under geoengineering or climate engineering.[9] The term has received endless criticism and avoidance, and understandably so; the threat of a state- or private-led climate engineering approach, without sufficient scientific understanding or governance to ensure responsible deployment, could lead to catastrophic consequences that are potentially more severe than the impacts of climate change itself. However, as many scholars have pointed out, the lack of political will to discuss and research these methods increases the risk of a rushed, mismanaged, or cursory deployment.[10]

It is first crucial to define the scope of these approaches, as climate engineering is a broad term encompassing various types of responses. A common definition provided by a Royal Society report from 2009 is, "Deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change."[11] This definition underscores two important aspects of the term: scalability and intent. While the climate engineering umbrella is large, it can be divided into two main categories: Solar Radiation Management (SRM), which aims to reduce the impacts of climate change through the reflection of radiation back into space but does not reduce greenhouse gas emissions, and the second, Carbon Dioxide Removal (CDR).[12]

CDR includes techniques which "reduce the levels of carbon dioxide (CO_2) in the atmosphere, allowing outgoing long-wave (thermal infrared) heat radiation to escape more easily."[13] While mitigation prevents the emission of greenhouse gases, CDR removes existing emissions. Under this definition, all forest-based mitigation fits within the CDR definition. Indeed, as many CDR technologies inherently parallel the aims and outcomes of natural sinks (carbon sequestration and storage), the line between mitigation and CDR becomes blurred and the answer to whether CDR is geoengineering looks more like a 'no.' However, while almost 90 percent of the climate models in the Intergovernmental Panel on Climate Change's (IPCC) latest report include some form of NET, there remains no governance structure for addressing the use of these technologies.[14] Without downplaying the real and serious dangers in anthropogenic climate forcing, or changing the balance between energy absorbed by earth and energy radiated out to space, it is important to remember the planetary-scale change humans have already caused. More importantly, it is crucial to consider the danger in denial.

One argument against developing climate engineering methods is the "slippery slope" argument. That is, field trials of the methods begin to look more and more like implementation, particularly as funding, political momentum, and vested interests increase.[15] Not without merit, this argument is also not unique to the world of climate engineering. The uncertain and

[9] Meysman and Montserrat, "Negative CO2 emissions," 1.
[10] Keith, *A Case for Climate Engineering*, 151.
[11] *Geoengineering the Climate*, 77.
[12] Ibid., ix.
[13] Ibid., 1.
[14] *Climate Change 2014: Synthesis Report,* 28.
[15] Keith, *A Case for Climate Engineering*, 150.

potentially risky nature of these methods demands discussion and should be the very impetus to regulate them.

Second, the "moral hazard" argument against climate engineering is that it can be used to justify continuing emissions.[16] Interestingly, this is the same argument that was initially made against adaptation—that if adapting to impacts was the focus, mitigation would be deprioritized. However, to date there has been no evidence of this. In fact, ten years after this argument was initially introduced, adaptation still struggles to compete with mitigation for attention, particularly in terms of finance.[17] If avoiding risky technologies is the aim, this conversation should provoke more urgency and ambition to decrease emissions, not less.

Finally, many of the arguments against climate engineering are made in the context of SRM not CDR. This points to the danger of the umbrella term as it is not yet clear whether marine CDR methods are truly climate engineering or if they are new mitigation methods. Regardless of the name, the growing support for the inclusion of these methods from the science community has yet to be translated into a policy platform.

While this conversation is largely absent in climate policy discourse, the IPCC has increasingly included CDR techniques in its assessments, namely Carbon Capture and Storage (CCS) and Bio-energy with Carbon Capture and Storage (BECCS).[18] However, these storage technologies do not address ocean acidification, can be costly, and have significant risks. Furthermore, marine carbon capture and storage, while there is lack of sufficient data, could potentially disrupt deep sea chemistry and harm nearby ecosystems.[19] There are many marine-based CDR methods that have been discussed with various levels of potential, including ocean fertilization, microbubbles to increase ocean albedo, and ocean upwelling. Ocean fertilization has been explored the most extensively in the context of conceptual models, as well as some field projects. However, field trials have not been overwhelmingly successful.[20] In addition, many of these techniques pose significant ecological risks and do not contribute to mitigating ocean acidification.[21]

The following section will focus on two types of marine CDR that have the potential to mitigate atmospheric CO_2 emissions, as well as ocean acidification: blue carbon and accelerated marine weathering with artificial ocean alkalization.

Enhancement of Marine Sinks

Blue Carbon

In recent years, natural climate solutions have gained increasing attention in the environmental advocacy and action space, but few are able to directly address emissions and acidification. One conventional approach that potentially mitigates both atmospheric CO_2 and addresses local ocean acidification is what has been termed "blue carbon."[22] Blue carbon, or the

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[16] Ibid., 135.
[17] UNFCCC, "Fact Sheet: Financing Climate Change Action."
[18] *Climate Change 2014: Synthesis Report*, 81.
[19] Herr and Galland, *The ocean and climate change*, 40.
[20] Nicholson, "The Promises and Perils of Geoengineering," 7.
[21] Williamson and Turley, "Ocean acidification in a geoengineering context," 4317-4342.
[22] Mcleod et al., "A blueprint for blue carbon," 552-560.

carbon sequestered and stored in coastal wetland ecosystems including mangroves, seagrass beds, and salt marshes, has the potential to be a low-cost carbon dioxide removal tool, as well as provide conservation and livelihood co-benefits.

Coastal wetland systems sequester and store blue carbon at much higher rates than their terrestrial counterparts.[23] It is estimated that 50 percent of carbon sequestered from the atmosphere is cycled through oceans, and 70 percent of this is in coastal wetlands.[24] This is a significant amount, as coastal waters comprise only seven percent of the world's oceans and are only 0.05 percent of plant biomass on land.[25] Because these systems remove atmospheric carbon at such high rates, their protection is paramount.

In addition to the ability of mangroves to filter nutrients in coastal waters, it has been found that seagrasses, specifically, are crucial in coastal calcium carbonate chemistry. Through an empirical model, one study found that these highly productive tropical seagrasses were responsible for an increase in pH of up to 0.38 units.[26] Depending on tidal fluctuations and water depth, this was found to potentially increase coral growth by approximately 18 percent.[27] This enhancement of coral reef resilience is an important finding and needs to be further researched.

However, these highly valuable, carbon-rich systems represent only a small portion of earth's surface. Unfortunately, they are also some of the most threatened systems on earth, with as much as 50 percent of all coastal wetlands having been lost over the past 50 years.[28] The loss of these ecosystems results in a variety of damages, not least of which is increased emissions. While blue carbon is sequestered and stored at relatively high rates, carbon from coastal wetlands is also emitted at a higher rate than from terrestrial systems when degraded. It is estimated that up to 19 percent of global emissions from deforestation are from coastal wetland loss, resulting in up to US$42 billion annually in damages, further underscoring the need to protect these systems.[29] There is a growing range of other economic valuation estimates that these systems provide, but increasingly, it is being found that marine ecosystems have been historically undervalued and actually represent a large portion of food, transportation, energy, tourism, and other markets.[30]

It is unclear how the blue carbon solution should be categorized. In many cases, coastal wetlands are conserved in order to help alleviate sea level rise and erosion, falling squarely in adaptation. Other projects expressly cite sequestration as their main aim. But if this is the case, is that sequestration carbon dioxide removal or mitigation? If it is mitigation, it can be supported within the United Nations Framework Convention on Climate Change (UNFCCC). Again, the line between these two strategies is softened, begging the question of distinction for policy-makers.

[23] Ibid., 1.
[24] Ibid.
[25] Nellemann and Corcoran, *Blue Carbon: A Rapid Response Assessment*, 6.
[26] Unsworth et al., "Tropical seagrass meadows," 5.
[27] Ibid., 6.
[28] Mcleod et al., "A blueprint for blue carbon," 552-560.
[29] Pendleton et al., "Estimating Global Blue Carbon Emissions," 5.
[30] Reuchlin-Hugenholtz and McKenzie*, Marine Protected Areas,* 5.

Accelerated Marine Weathering and Enhanced Alkalization

Chemical weathering—the breakdown of rocks and minerals over time—is a natural process which stores carbon in the seafloor, but which occurs over long geologic time scales, far slower than the rate of anthropogenic CO_2 emissions.[31] Accelerated weathering and enhanced alkalization are a collection of techniques that accelerate these already present carbonate and silicate weathering reactions. These techniques span a spectrum of methodologies, principally to introduce additional, globally abundant base minerals into this cycle. In doing so, the carbon uptake that naturally occurs happens faster and seawater alkalinity increases with the introduction of additional carbon-based ions, combatting ocean acidification.[32]

There are many different variants of this model, most of which remain theoretical, though there have been some promising field trials including for liming—the addition of calcium carbonate to coastal waters—and olivine weathering—the addition of olivine materials. However, there are also significant drawbacks. The largest barriers are surrounding cost and scale. In order for weathering to be implemented on a scale large enough for significant mitigation and alkalization, the state of the technology now would be close to the cost of CCS, but with less storage potential.[33] Additionally, the acquisition and transport of necessary mineral material would likely require enormous amounts of energy use and mining. Similarly, in terms of alkalization, counteracting the changes in acidity of an average uptake of two gigatons (Gt) of carbon per year would require roughly 20 Gt of calcium carbonate ($CaCO_3$) per year. For a limestone layer 100 meters thick, this would require the removal of roughly 60 km^2 each year.[34] For this to be feasible, source material would need to be coastally located, otherwise transportation costs and footprint would be prohibitive. This approach might be better suited for local or regional ocean acidification mitigation purposes on the reef, fishery, or ecosystem level, with an added benefit of sequestration.[35]

The mechanism behind this process has been confirmed in numerous studies and models, but there are still several important challenges in understanding and quantifying these methods. A better understanding of CO_2 sequestration efficiency under field conditions needs to be more closely monitored.[36] Conventional methods, such as sustainable fisheries management and protection of coastal wetlands, should be employed to build resilience in these systems while simultaneously conducting further research into more unconventional marine CDR methods, such as accelerated weathering.

Marine CDR in the UNFCCC

Due to the transboundary and global character of marine systems and processes, marine sinks and CDR should be considered within the scope of international law. While the creation of large bureaucratic institutions to tackle environmental issues takes enormous amounts of political will, logistical capacity, and resources, existing institutions provide the framework

[31] *Geoengineering the Climate*, 9.
[32] Meysman and Montserrat, "Negative CO2 emissions," 1.
[33] Billé et al., "Taking Action Against Ocean Acidification," 770.
[34] *Ocean Acidification*, 37.
[35] Feng et al., "Could artificial ocean alkalinization protect," 10.
[36] Meysman and Montserrat, "Negative CO2 emissions," 3.

necessary to expand and structure the conversation around the ocean-climate nexus. There are multiple possible entry points for enhancement of marine sinks in the context of emissions removals under current international treaties. The following section will review entry points into international climate policy, as this research is specific to the carbon sink capacity of marine systems. However, it is important to note that other environmental regimes, most notably the Convention on Biological Diversity, the London Convention, and the Law of the Sea, are also necessary to consider for marine CDR, as well as other ocean-climate linkages.

The United Nations Framework Convention on Climate Change (UNFCCC) is the most appropriate regime for enhancement of marine sinks specifically, as it has a wide participation of 197 parties to the convention, a large scope, and shares the main objectives of CDR: preventing dangerous interference with the climate system and allowing ecosystems to adapt to climate change. This parallel can be seen in the Convention itself, under Article 2, The Objective:

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would *prevent dangerous anthropogenic interference with the climate system*. Such a level should be achieved within a *time frame sufficient to allow ecosystems to adapt naturally* to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.[37]

The importance of oceans can be found throughout the Convention, starting with the special emphasis it puts on the climate system as a whole. It also specifically recognizes the importance of oceans as sinks and reservoirs, stating in the Preamble that the parties are "aware of the role and importance in terrestrial and marine ecosystems of sinks and reservoirs of greenhouse gases."[38] It is also noted in Article 4.d. that they aim to:

> Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems.[39]

This is a clear acknowledgement of the need to protect and enhance marine sinks.

As the Conference of Parties (COP), the governing body of the UNFCCC, has grown, new entry points for enhancement of marine sinks have emerged under the UNFCCC. At COP 17, the Subsidiary Body for Scientific and Technological Advice (SBSTA) invited parties to:

> Provide information on the technical and scientific aspects of emissions by sources, removals by sinks, and reservoirs of all greenhouse gases, including emissions and removals from coastal and marine ecosystems such as mangroves, tidal salt marshes, wetlands and seagrass meadows.[40]

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[37] United Nations, "UNFCCC," 1992, Article 2; emphasis added by author.
[38] United Nations, "UNFCCC," 1992, Preamble.
[39] United Nations, "UNFCCC," 1992, Article 4.
[40] *Report of the Subsidiary Body*, 2011.

Since then, multiple parties and negotiating blocs, such as Norway, the Coalition for Rainforest Nations (CfRN), and The Gambia have given informal, independent submissions on coastal marine sinks to the UNFCCC.[41]

Perhaps the most notable entry point for marine CDR within the UNFCCC is within the very goals of the Paris Agreement and the global temperature goal of "well below 2 degrees."[42] While the two-degree goal is reported as the benchmark of the Paris Agreement, the long-term cooperative action goal of net-zero emissions by the second half of the century is also important. Unfortunately, the Agreement offers no direction if this target is not achieved. Likewise, while the ambition mechanism and review process have timelines, there is no timeline to reach individual or global targets. However, the long-term goal does highlight science, equity, and sinks:

> In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.[43]

While this does not explicitly call for CDR technologies, it sets precedent to act under the best available science, as well as the central role of removals by sinks. It also does not specify in what way the balance of sources and sinks will be achieved. Under the definition of mitigation, sinks are included, again raising the question of whether CDR is really another type of mitigation.[44] CDR *de facto* represents an implementation mechanism for meeting the objective of the UNFCCC.[45] While enhancement of sinks is clearly included, the Convention does not make specific reference to CDR, again underlying a need for clarification of the difference. Furthermore, many components of the UNFCCC and subsequent agreements are implicitly relevant to CDR, such as the importance of natural sinks and efforts to minimize adverse effects to the environment.

Certain qualities of marine CDR can contribute to a successful enabling environment, including science-based targets, enhancing coverage of sectors, promotion of mitigation actions with an emphasis on co-benefits, and common rules for accounting, all of which enhancement of marine sinks can contribute to.[46] In addition, the core elements of the Paris Agreement—an ambitious target, the inclusion of removals, and the commitment to achieve a balance between emissions and removals—all include marine CDR. These provide the framework for future development and expansion, including procedural mechanisms and an emphasis on capacity building and transparency, as is discussed in further detail below.

[41] UNFCCC, "Submissions from Parties," 2014.
[42] UNFCCC, "The Paris Agreement," 2015, Article 2.
[43] UNFCCC, "The Paris Agreement," 2015, Article 4.
[44] Craik and Burns, *Climate Engineering under the Paris Agreement*, 6.
[45] Ibid.
[46] Murray and Vegh, *Incorporating Blue Carbon as a Mitigation Action*, 6.

Marine CDR in the UNFCCC: Recommendations

At the broadest level, the UNFCCC Conference of Parties should draft a decision on the importance of oceans to both the climate system and to livelihoods and vulnerable populations. This would signal a recognition to the ocean policy and science communities that may motivate a more robust effort to incorporate ocean conservation into strategies and catalyze additional emissions reductions, increasing ambition. Increased ambition, as referenced in climate policy, refers to the collective will to cut greenhouse gas emissions in order to meet the temperature goal.[47] In the context of marine sinks, party-level ambition should be met with strengthened high level guidance as multiple parties have expressed interest in better inclusion of domestic marine sinks, but often lack sufficient instruction from the UNFCCC on how to do so.

Similarly, as the UNFCCC is the main international instrument responsible for governing greenhouse gases, ocean acidification should be better discussed. Soon after ocean acidification first gained recognition from the Association of Small Island States (AOSIS) in 2009, it was recognized as a slow onset event, but is still viewed as a symptom of climate change, rather than a concurrent problem.[48] Shifting this perception would allow states to better incorporate ocean acidification into their strategies and would encourage drastic emissions reductions.[49]

Scholars have proposed various recommendations for addressing ocean acidification specifically in the UNFCCC, including a working group in SBSTA to provide ocean acidification priorities.[50] Ocean acidification and other ocean impacts should also be considered under the contexts of adaptation and even loss and damage, the current framework to address slow-onset impacts, climate-induced migration, non-economic losses, and other damages that can relate to ocean populations.[51] Others have argued that while temperature is an appropriate target for atmospheric carbon emissions, there should be additional scientifically-determined targets or goals to reinforce the action needed for oceans. This could be a more symbolic target or an empirical one such as pH, recognizing that current goals may not be enough to combat ocean acidification.[52]

In terms of blue carbon specifically, many Parties have included coastal and marine ecosystems in independent submissions, as well as their Nationally Determined Contributions (NDCs), to the Paris Agreement.[53] However, there remains a large gap in blue carbon inclusion from coastal countries, underscoring the need for an international approach.[54] In order to facilitate this, the IPCC Task Force on National Greenhouse Gas Inventories released a 2013 Wetlands Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. This supplement provides updated methodological guidance specific to coastal wetlands, including prevention of double counting, effects of different management practices, and

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[47] Cameron and DeAngelis, "What is Ambition?," November 26, 2012.
[48] UNFCCC, "Submissions from Parties," 2014.
[49] Billé et al., "Taking Action Against Ocean Acidification," 766.
[50] Williamson and Turley, "Ocean acidification in a geoengineering context," 4317-4342.
[51] UNFCCC, "Warsaw International Mechanism," 2013.
[52] Harrould-Kolieb, "Ocean Acidification and the UNFCCC," 14; Harrould-Kolieb and Herr, "Ocean acidification and climate change," 378-389.
[53] Herr and Landis, *Coastal blue carbon ecosystems*, 6.
[54] Ibid., 25.

restoration methodologies.[55] To date, these accounting guidelines are voluntary and the UNFCCC is currently accepting submissions on the experience and lessons learned by parties in relation to the supplement so that they can be updated in 2019. This period of review is helpful, and coastal accounting should continue to be discussed across parties so that the next version can be improved and perhaps made mandatory. Workshops around the guidelines' implementation would be helpful to share knowledge and progress their use.

In addition to national accounting, the IPCC should continue to cover marine CDR in its assessment and special reports. There are clear signals of this, including the upcoming Special Report on Global Warming of 1.5 degrees Celsius, as well as the Special Report on Oceans and the Cryosphere. According to the publically available outlines, these reports are set to include topics such as ocean climate linkages and feedbacks, ecosystem services including carbon uptake, and marine mitigation. They will also address nature-based mitigation like "blue carbon including changes in carbon stocks and fluxes under emission pathways, their relevance for greenhouse gas inventories and accounting," and technologies including "climate engineering techniques, their feasibility and risks, ethical aspects."[56] Finally, the IPCC Sixth Assessment Report is to be completed in time for the upcoming Global Stocktake in 2023, which will also help advance the discussion of enhancement of marine sinks. Together, these reports outlining the latest science and the current state of play will likely inform and shape the long-term mitigation goals as well as parties' responses.

Marine CDR should also be considered in the Paris "Rulebook," the framework currently under negotiation that will ultimately decide the operationalization of the agreement, which includes the rules, processes, and guidelines for parties on how to proceed. Perhaps most importantly, the rulebook will guide ambition, including the implementation of current NDCs, the development of the next round of NDCs, and long term action strategies. Accordingly, the rulebook should address how to include marine CDR in terms of both adaptation and mitigation in the context of the ambition mechanism, including NDCs, long term actions, and other submissions.

Finally, with additional research, marine sinks could be better included in finance flows and cooperative action. Though currently rare in the ocean context, market mechanisms, such as nutrient trading and payments through user fees or taxes on commercial enterprises, could be effective if used responsibly. Market-based mechanisms for a blue carbon Verified Carbon Standard (VCS), modeled off of the Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) program, may also be possible in the near future. Ideally, a long-term financial mechanism with an emphasis on public-private partnerships for increased research and inclusion of marine sink projects for climate funding would be included under Article 6 of the Paris Agreement.

Conclusion

A UNFCCC working group on removal technologies is needed to construct a regulatory framework for these technologies before deployment, particularly in the context of marine CDR. An assessment of different methodologies and their respective effectiveness, feasibility,

[55] *2013 Supplements to the 2016 IPCC Guidelines: Wetlands*, 2013.
[56] IPCC, "Publications and Data," 2016.

scalability, cost, and sustainability is necessary through the research phase. Further, as recommended by the Forum for Climate Engineering, a decision-making body under the UNFCCC that can negotiate deployment, as well as a monitoring, review, and verification process are crucial. Through these measures, specific proposals—including various types of CDR—can be debated, while encouraging low-risk, high-reward projects.

It is widely accepted that the best response to the mounting problems from the rising global temperature is to decrease emissions from burning fossil fuels and degraded natural systems. Unfortunately, we have passed the point of needing emissions reductions alone, and have entered an era that requires an honest conversation on next steps in light of this urgency. These steps are better inclusion of the earth's largest carbon sink, the oceans, into the Paris Agreement and the reshaping of the discussion around adaptation, mitigation, and CDR. Perhaps instead of three distinct groups, these strategies can form synergies with projects seeking to have components of all of them.

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Table of Abbreviations

AOSIS	Association of Small Island States
BECCS	Bio-energy with Carbon Capture and Storage
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CfRN	Coalition for Rainforest Nations
COP	Conference of Parties
IPCC	Intergovernmental Panel on Climate Change
NDCs	Nationally Determined Contributions
NET	Negative Emissions Technologies
REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
SBSTA	Subsidiary Body for Scientific and Technological Advice
SRM	Solar Radiation Management
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard

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