Marine Carbon Dioxide Removal Research Plan (US NSF Call for Input)

Input from the Deep Ocean Stewardship Initiative
The Deep Ocean Stewardship Initiative (DOSI) (www.dosi-project.org) is a global network of experts which seeks to integrate science, technology, policy, law, and economics to advise on ecosystem-based management of resource use in the deep sea.

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1. How would a Marine CDR Plan affect you, your organization, or your community?

We represent a scientific network focused on the deep ocean. Many of the proposed mCDR technologies identify the deep ocean as a carbon repository. Our community of scientists and other deep ocean stakeholders (over 3000) has much to offer to understanding the fate of carbon deposited in the deep ocean, consequences for marine ecosystems, and mCDR effectiveness. The research plan may stimulate additional research or reshape existing programs. New mCDR research may help grow the network, create new partnerships and advance open data access.

2. *What questions or concerns do you have about the regulation of marine CDR, including marine CDR research? What tools or resources should the Federal Government provide to support the safety and effectiveness of marine CDR research, including testing at scale in the field? What knowledge exists, and what additional knowledge is needed to inform the safe and effective regulation of marine CDR research? What knowledge exists and what additional knowledge will be needed to inform decisions about the readiness of any marine CDR approach for full-scale deployment or commercial application?*We are concerned that insufficient attention and resources has been given to environmental and ecosystem perturbation associated with large-scale mCDR deployment, particularly for the deep ocean. A large-scale research initiative

on environmental risk is needed to inform decisions about deployment, involving cross communication and collaboration across mCDR technologies.

Large parts of the vast deep sea are poorly characterized both environmentally and biologically. To fully understand the consequences of the deployment of CDR initiatives and their impacts on the deep-sea environment, environmental and biological baselines will be needed, a task that based on other activities (e.g., environmental and biological assessment for deep-sea mining) could take years if not decades. Additionally, a thorough review is needed of the existing scientific literature that addresses the fate and sequestration of carbon reaching the deep sea/seafloor and factors that affect carbon sequestration. Most existing published knowledge is local and research is required on how to extrapolate this to larger space and time scales. The vast array of existing knowledge (some of these technologies were researched > 20 y ago) should be synthesized and combined with expert advice to enable decision making.

Funding resources are required for (a) experimental, field small-scale and modeling- ecological forecasting marine CDR research; (b) transfer of small-scale field knowledge generation into medium and large scale mCDR deployments. Technical and scientific expertise must be recruited across latitudes (especially in the global south) before engaging in mDCR. The scale of existing knowledge is a snapshot and cannot inform decisions in the immediate time scale about the readiness of any marine mCDR approach for full-scale deployment or commercial application that is large scale.

Finally, we suggest that potential benefits of mCDR for reaching climate goals are carefully weighed in relation to impacts on other aspects of ocean, climate and broader environmental sustainability. We are concerned that a hastened agenda to fast-track enabling regulation for mCDR may have significant negative impacts on deep-ocean ecosystems and species, which also play key roles in Earth systems.

3. W*hich marine CDR techniques or what aspects of marine CDR do you believe the Federal Government should prioritize for research? Are there particular marine CDR approaches that you believe are especially promising with regard to climate change mitigation, ocean acidification, or other benefits? Are there particular marine CDR approaches that you believe are particularly more or less risky with regard to the environment, public health and communities, or other uses of the sea?*We suggest the following priority research themes:

1. Understanding the effective carbon sequestration potential of each proposed technique before mCDR initiatives begin. This issue is intimately linked with the specific locations where CDR initiatives will take place. Location of deployment is key to understanding the specific ecosystem and biodiversity impacts, and and to enable marine spatial planning.

2. Most mCDR initiatives will need to be scaled up to sequester relevant amounts of carbon for climate mitigation. The consequences of this scale up, including potential negative feedbacks, and impacts on natural ecosystems is a key question. Also, it is essential to understand how ocean processes are affected that lead to changes in public health, coastal communities and their use of resources in the sea.
3. The subsurface injection of liquid CO2 into geological formations (> 100 m below the substrate) or existing wells may pose the least risk to the marine environment of proposed technologies, but the potential for and consequences of leakage for marine ecosystems and the carbon cycle require study. Experiments, field measurements and modeling mCDR approaches should focus on microbial and other processes several hundreds of meters below the substrate.
4. Unintended side effects of mCDR need to be understood, prevented and studied comprehensively (long-term) for ecological monitoring to continuously assess environmental impacts and carbon sequestration effectiveness (which has not been illustrated to date for any technology). Side effects could include potential ocean deoxygenation, acidification and alterations to local food webs. There is a need for comprehensive studies on the long-term impacts on marine chemistry and ecosystems.

4. *What kinds of information about marine CDR would be most helpful for the Federal Government to make available to the public, research community, and other stakeholders? How should the government engage marine CDR stakeholders and the public, including Indigenous communities and communities that may be affected by marine CDR?*The public, researchers and policy makers need information that will allow them to evaluate tradeoffs in determining viability of mCDR deployments: environmental, energy, monetary, and social.

The public should be made aware of potential changes in marine ecosystems (biodiversity, community structure, functions and ecosystem services), impacts on marine habitats, ecosystem engineers, fish, fisheries, sediments (and ultimately livelihoods). How will mCDR deployments affect the natural carbon cycle? Ocean productivity and fisheries? How will these affect additionality of Carbon removal actions? What is the energy expenditure per unit carbon sequestered ? How long will the carbon remain sequestered?

The Federal Government should provide a framework or roadmap that represents a way forward in the climate change crisis. This must engage the deep-sea community and stakeholders in guiding long-term response and large spatial scales that will affect future generations. The slow pace of deep sea ocean processes and response must be incorporated. Science is needed to study, describe and forecast geochemical cycles (e.g. Carbon, Nitrogen), their changes in large time and space scales engaging existing observing systems (floats, moorings, ship tracks and observatories) and using new technological approaches.

5. *What are the most significant marine CDR efforts being undertaken by academia, industry, philanthropy, non-governmental organizations, and other governments that the Federal Government should be aware of? What factors should the Federal Government take into account when considering potential partnerships between these entities and the Federal Government? What are the biggest challenges that the Federal Government and potential partners may face in collaborating, and how could the Federal Government help overcome these challenges? What examples of partnerships are most relevant to potential marine CDR partnerships*?
The Federal Government should call for a large-scale research initiative that combines study of the carbon cycle in the open/deep ocean (> 200 m) and how alteration of marine ecosystems by large-scale mCDR deployment will affect the regulatory, provisioning, supporting and cultural services provided . It would also be relevant to consider the price of carbon related to mCDR on the financial markets (compliance markets and voluntary markets), and compare it to the social cost of carbon.

There are existing programs focusing on OA and mCDR that include industry and academia and have offered an initial funding through NOAA. This should be expanded in amount and time to include the deep ocean. Among the biggest challenges is that enterprises of the scale of mCDR require partnership not just within entities and the Federal Government but with other nations. The vastness of the ocean and its high connectedness requires new approaches that combine disciplines (physical oceanography, biogeochemistry, ecology). Enhanced ocean literacy is also required to expand entities involved in mCDR efforts and to strengthen local, national and international partnerships.

6. What else would you like the Federal Government to consider as it develops a Marine CDR Plan?
The deep ocean has been largely missing in action from major reviews (e.g., National Academy, GESAMP), research agendas, industry conversations and presentations. It is harder to study and less is known but remains one of the more pristine sets of ecosystems on the planet. Please ensure that the possible contributions and vulnerabilities of deep-ocean processes and ecosystems are a significant part of any federal mCDR research plan. Please see *Levin, Lisa A., Joan M. Alfaro-Lucas, Ana Colaço, Erik E. Cordes, Neil Craik, Roberto Danovaro, Henk-Jan Hoving, Jeroen Ingels, Nélia C. Mestre, Sarah Seabrook, Andrew R. Thurber, Chris Vivian, Moriaki Yasuhara. 2023. Deep-sea impacts of climate interventions. Science 379: 978-981.*
This is available at: https://www.science.org/stoken/author-tokens/ST-1072/full

We need experiments, field work and modeling efforts that include all relevant time and spatial scales and that include depths below 200 m, EEZ and ABNJ in a collaborative effort with different entities, stakeholders and international partnerships. Ocean connectivity guarantees that national mCDR actions will affect waters and ecosystems outside their borders/EEZs. Explore

and advance seafloor and subseafloor state of the art sampling capabilities, approaches and critical science questions for the near, intermediate and long-term future. Also, involve existing technologies, map existing legacy data to develop clear forward thinking in CC solutions. Do not wait to consider the deep sea and its seafloor processes as important actors in mCDR research and policy.

The phrasing of the US mCDR Research Plan needs to incorporate ideas of safe mCDR, safe size and location of deployment, and necessary protections and precautions.

We suggest any trade-offs, risks and benefits of mCDR are considered within a holistic framework including not only climate mitigation but also biodiversity protection and ocean sustainability. This may provide a different outcome compared to evaluations in relation to the more narrowly framed goals of the Paris Agreement.