



Submitted via electronic mail on April 23, 2024

Esteemed Members of the National Science Foundation,

Climate Vault applauds the National Science Foundation (NSF) and the White House National Science and Technology Council Marine Carbon Dioxide Removal Fast-Track Action Committee (MCDR-FTAC) in their efforts to implement an impactful Marine CDR Plan (“mCDR Plan”) to advance the goals of the Ocean Climate Action Plan. We appreciate the opportunity to submit a response to this RFI and look forward to continuing to engage with the NSF and MCDR-FTAC as this work evolves.

Introduction to Climate Vault

Climate Vault, Inc. (“Climate Vault”) is a 501(c)(3) non-profit organization founded at the University of Chicago with the mission to simultaneously reduce carbon emissions and support innovation in carbon dioxide removal (CDR) technologies. Our founder, Dr. Michael Greenstone, is a renowned economist who co-led the development of the United States social cost of carbon under President Obama. At Climate Vault, we believe in the power of markets to solve complex challenges.

Our CDR solutions are vetted by our world-class Technology Experts Chamber (“Tech Chamber”), which includes science and policy experts from Harvard, MIT, Princeton, and UC San Diego (Scripps). The Tech Chamber is chaired by former US Energy Secretary, Ernest Moniz.

Our Tech Chamber assesses CDR technologies across three pathways: Terrestrial, Technological, and Oceanic. Given the ocean’s size and natural capacity as a carbon sink, we believe mCDR solutions are imperative to helping the U.S. achieve net-zero by 2050 and collective global efforts to limit warming to 1.5°C above pre-industrial levels. However, we acknowledge that mCDR solutions are currently immature and that a dedicated, coordinated research effort to answer critical questions and overcome roadblocks to growth and expansion is needed to advance these solutions.

Climate Vault’s Response to Select RFI Questions

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

Climate Vault is a 501(c)(3) non-profit organization with the mission to simultaneously reduce carbon emissions and support innovation in carbon dioxide removal (CDR) technologies. Through our annual RFP process, we seek to identify innovative CDR technologies to receive grant funding, and thereby support the growth and development of the carbon removal ecosystem. In Climate Vault’s recent RFP round, mCDR solutions comprised 15% of applications received. However, while Climate Vault and the Tech Chamber agree that these mCDR solutions show promise, most lack technical maturity and face common challenges to scaling their solutions. Some examples include: demonstrating the technical feasibility and scalability of their technologies; implementing clear monitoring, reporting and verification (MRV) processes; obtaining permits to implement pilot facilities; and identifying and addressing project impacts on local communities and ecosystems. Therefore, Climate Vault maintains that any guidelines that help to move mCDR solutions forward are worth pursuing.



There are two key ways that the mCDR Plan would support our mission to accelerate mCDR innovation:

- **Address critical barriers to adoption and scaling:** The mCDR Plan would bring clarity and certainty to the common challenges cited above. It could help to reduce the inherent and perceived risks related to these projects, ultimately encouraging greater adoption of mCDR technologies. This clarity, supporting data, and risk reduction could also lead to greater success for project developers applying for funding and investment opportunities, such as through Climate Vault's grant program.
- **Amplify the climate impact of each grant dollar awarded:** The mCDR Plan would help to alleviate costs for internal research, development and deployment efforts for mCDR project developers, thereby lowering the all-in cost to remove 1 tCO₂ and enabling Climate Vault to make a bigger impact per grant dollar awarded to successful applicants.

More broadly, the mCDR Plan can have positive impacts for local communities and economies:

- **Quantification of socioeconomic benefits:** The mCDR Plan could help to identify and quantify the socioeconomic benefits of mCDR solutions in local communities. In doing so, the mCDR Plan will equip project developers, advocates and key decision-makers with the data-backed insights necessary to facilitate further adoption and implementation of these technologies.
- **Creation of new jobs and scaling of the green economy:** Following the further adoption and expansion of mCDR solutions, the mCDR Plan will help to foster and scale a new industry of green jobs with positive local economic impacts.

2. **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 will be needed to inform decisions about the readiness of any marine CDR approach for full-scale deployment or commercial application?**

Engage with the International Scientific Community

There is significant work to be done to move the mCDR space forward in a manner and time frame that meets the challenge of the global climate crisis. Therefore, Climate Vault encourages the Federal Government to prioritize engagement with the organizations and institutions that are already conducting valuable mCDR research (e.g. Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, Ocean Visions), in order to accelerate the collective rate of progress. This outreach should be conducted as part of a comprehensive stakeholder engagement exercise, discussed in further detail in our response to Question 4.

Establish Standards for Research Practices

Climate Vault also encourages the Federal Government to develop standards to guide collective research practices under the mCDR Plan to support safety, effectiveness, accountability, and collaboration across all research activities, including field testing. These standards should:



- Seek to identify and mitigate potential ecological and socioeconomic risks resulting from research activities and field experiments.
- Include regular, independent assessments of program performance in order to maintain accountability, while not placing unnecessary burdens on research efforts and hampering progress.
- Promote the standardization and sharing of data across disciplines and via public forums to foster transparency and collaboration.
- Build in flexibility so that research needs and approaches can be adjusted to account for the latest scientific evidence, as it comes available.
- Identify what length of sequestration will be deemed acceptable for the research. For example, some researchers have argued that 100-year sequestration should be acceptable because it will provide relief from near-term impacts of CO₂ (e.g., warming, acidification in some regions, etc.) while providing insight into the scalability of mCDR techniques and their environmental impacts.

Additionally, the Federal Government could consider developing standards that are aligned with existing international agreements, such as the United Nations (U.N.) Convention on the Law of the Sea (UNCLOS); the London Protocol; and the U.N. Convention on Biological Diversity (CBD). Doing so could help to reduce any potential future friction in research activities, should the U.S. ratify these agreements or if the mCDR Plan requires collaboration with international bodies for research and field experiments.

Prioritize Critical Needs and Common Hurdles

Based on Climate Vault's research, engagement with the CDR community, and learnings from our RFP process, we suggest that the mCDR Plan focus research efforts in the following areas to advance mCDR initiatives and scale impactful solutions:

Monitoring, Reporting and Verification (MRV)

Given the nascentcy of the CDR space and the complexity of the ocean, developing MRV standards and regulations is crucial to developing confidence in mCDR solutions. While a few mCDR protocols have been developed by various standards bodies to date, there is no industry-wide consensus for implementation and management. Moreover, there is little consensus at the federal level regarding what mCDR MRV approach(es) are acceptable, how carbon sequestration should be demonstrated, and where research should be allowed to take place. Therefore, Climate Vault encourages the Federal Government to host large-scale workshops with the scientific community to advance discussions and align disparate perspectives on these topics at a national, and potentially international, level.

First and foremost, the Federal Government should determine which mCDR MRV approach(es) it will require or deem acceptable under the mCDR Plan. Given the predominant schools of thought on this topic, this means clarifying whether mCDR projects and research should: demonstrate carbon sequestration potential and environmental impacts (often referred to as "eMRV") collectively; demonstrate carbon sequestration potential first, after which environmental impacts can be researched and factored into decision-making; or whether both approaches are acceptable. In each case, there is also the question of whether carbon sequestration is best demonstrated by directly measuring sequestered CO₂, measuring ocean oxygen levels, or whether modeled results will be accepted for some parameters. All three approaches have been discussed by the scientific community, but there is no consensus on what should be



required to demonstrate sequestration. The Federal Government should make clear what standards of demonstration will be acceptable.

Additionally, community discussions must address where research can take place. While there are a few instances of very small-scale projects taking place in territorial waters, the Federal Government must determine whether mCDR projects will be allowed to take place in the economic exclusion zone (EEZ) and should develop a framework for identifying optimal test sites. Moreover, if projects are permitted to take place in the EEZ, the Federal Government should clarify whether it plans to indemnify federally-funded project developers and research initiatives operating in the EEZ, should any direct or indirect negative impacts result from the tests, in order to bolster confidence in and support the scaling of thoughtful mCDR projects. Finally, it is important to note that some techniques could not be tested adequately in the EEZ because the conditions necessary for the techniques do not exist in the EEZ. If there is a stipulation that projects only be conducted in the EEZ, this will eliminate some techniques from research consideration.

The government's requirements (or range of acceptable approaches) for mCDR MRV should be clearly outlined. Climate Vault also encourages the government to host community workshops to provide guidance on the requirements to ensure understanding and compliance among relevant stakeholders.

Environmental, Ecological and Community Impacts

Potential mCDR impacts on ocean chemistry, local ecosystems and shoreline communities is an important research area. The climate crisis calls for scaling mCDR solutions quickly, but the urgency to sequester carbon must be balanced with reasonable efforts to avoid causing undue harm. Understanding upstream and downstream impacts of mCDR projects will help address key stakeholder concerns and enable the scaling of thoughtful, well-managed mCDR projects.

Permitting

Navigating the permitting system is time-consuming and resource-intensive for mCDR project developers. The system is complex and fragmented with many local, regional, national, and international regulations and institutions that govern activities within maritime zones. These regulations were not designed specifically for CDR projects, which leaves many questions regarding how mCDR project developers should comply. The mCDR Plan can provide clarity on the types of permits required for different CDR projects, the processes and requirements for obtaining the permits, and where necessary, working with regulators to resolve key information gaps and streamline compliance.

Finally, each of the above research areas can be best supported through the development of advanced oceans systems modeling tools. For example, tools that model ocean system interactions can be used to develop baselines for MRV activities and predict the range of potential outcomes or direct impacts to the ocean resulting from different mCDR approaches. Additionally, ocean modeling systems can be used to develop sophisticated planning tools, which can be used to help regulatory bodies and project developers identify optimal site locations to implement test pilots or expand existing facilities.



3. Which marine CDR techniques 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?

Climate Vault does not believe that research efforts and field trials have progressed far enough to conclude which mCDR approach(es) are most promising. Climate Vault maintains that researching and developing a variety of mCDR solutions simultaneously is critical to identifying which solution(s) are most effective and scalable. However, Climate Vault encourages dedicated research efforts on the following solutions:

Blue Carbon

Blue carbon projects face significant challenges to scaling and permanence; however, they have significant carbon sequestration capacity and are essential to coastal resilience, supporting wildlife habitats and biodiversity, and bolstering local economies, such as fisheries. Climate Vault views blue carbon projects as a key component of the mCDR landscape and suggests dedicated research on:

- Modeling and quantifying sequestration rates and capacity based on variability in environmental settings and hydrological conditions (e.g., soil and sediment depth, proximity to open water, water circulation, and wave activity).
- Identifying and quantifying climate change impacts on sequestration potential and permanence (e.g., sea level rise, rising temperatures), as well as using this data to predict and better manage future blue carbon projects.
- Opportunities to use soil additions or plant cultivars to enhance sequestration and quantify the impacts of these methods.
- Framework development for identifying preferred site locations for new or expanded blue carbon projects, including opportunities to restore degraded coastal areas, incorporate wetlands into adaptation projects, and convert hardened shorelines to natural shorelines.
- Comprehensive mapping and data sets for blue carbon stocks.
- Quantifying resilience benefits of blue carbon projects for coastline communities.

Moreover, given the impacts that climate change can have on coastal communities, such as damage caused from more frequent and intense storms and sea level rise, Climate Vault encourages the Federal Government to identify collaborative opportunities among blue carbon project developers, local governments, and federal agencies (such as FEMA) for identifying optimal sites for blue carbon projects and tracking and quantifying impacts.

Macroalgae

Macroalgae projects are unique because they do not compete with arable land or require fresh water, and some of the infrastructure and operations are already in place and could be used for future expansion. However, much remains unknown about the effectiveness and impacts of sinking significant quantities of macroalgae to the deep ocean. Therefore, Climate Vault suggests dedicated research on:

- Ecological and biological impacts resulting from the growth, collection, harvesting, and sinking of various amounts of macroalgae in different marine environments and sea depths.



- Ocean modeling systems to quantify the amount of CO₂ sequestered through macroalgae growth and harvesting activities.
- Tracking systems to determine the amount of biomass that reaches the ocean floor and is effectively sequestered.
- Opportunities to use plant cultivars to increase embodied carbon and yields.
- Framework development for identifying preferred site locations for macroalgae projects.
- More efficient, cost-effective technologies for harvesting and sinking macroalgae at sea.

Ocean Alkalinity Enhancement

While the chemistry behind Ocean Alkalinity Enhancement (OAE) is well-understood, most OAE research to date has been confined to modeling and lab studies. Field trials are needed in order to better observe and quantify the upstream and downstream impacts of this mCDR approach and to develop more precise accounting for carbon sequestration capacity. Therefore, Climate Vault suggests dedicated research on:

- Quantifying the upstream environmental impacts from mining, grinding and transporting alkaline materials to application sites.
- Identifying and addressing the downstream environmental and socioeconomic impacts from alkaline material application, including effects on ocean chemistry, local ecosystems and shoreline communities.
- Establishing strict purity standards for alkaline materials, with the goal to minimize the presence of trace metals or other pollutants introduced into seawater through OAE applications.
- Framework development for identifying preferred site locations for OAE projects, including projects taking place in the open ocean, on beaches, or in on-shore facilities using coastal outfalls.
- Advancing models and tools used to monitor and verify the amount of CO₂ sequestered.

Direct Ocean Capture

Direct Ocean Capture (DOC) has significant potential as a mCDR approach; however, these projects remain in earlier stages of development and implementation. Therefore, Climate Vault suggests dedicated research on:

- Identifying low-cost, energy-efficient DOC methods; in particular, the mCDR Plan should consider aligning with existing research efforts through the DOE/ARPA-E Direct Ocean CO₂ Capture Program.
- Ecological and biological impacts resulting from the intake and processing of large quantities of seawater.
- Framework development for identifying preferred site locations for DOC facilities and opportunities to potentially co-locate with existing infrastructure.
- Advancing models and tools used to monitor and verify the amount of CO₂ sequestered.

4. How should the government engage marine CDR stakeholders and the public, including Indigenous communities and communities that may be affected by marine CDR?

Stakeholder engagement is a critical component of the project planning process. For mCDR projects in particular, public acceptance is also a roadblock to advancing further research and testing. Engaging in



intentional and continuous dialogue that prioritizes equity, with relevant stakeholders, and implementing feedback accordingly, is important to advancing mCDR solutions. Climate Vault encourages the NSF to incorporate the following into their process:

1. **Identify stakeholder groups:** Conduct an in-depth review of relevant stakeholder groups, including communities that may be adversely impacted by the mCDR Plan.
2. **Establish robust communication:** Engage in transparent and balanced communications with identified stakeholders groups. This includes hosting regular community education and discussion forums regarding the benefits, challenges and risks involved with mCDR technologies and related research initiatives. Additionally, a formal feedback mechanism should be created to ensure all stakeholder perspectives are represented.
3. **Implement targeted research efforts and programs:** Based on stakeholder feedback, devise targeted research efforts and programs that address the most pressing or impactful environmental, social, and economic considerations. In particular, the NSF may consider organizing small-scale pilots where co-benefits can be demonstrated and realized in local communities. Quantifying outcomes and potential co-benefits will also provide project developers and advocates with the data they need to gain acceptance and enable the scaling of their technologies.
4. **Track and measure progress:** Implement robust data collection and monitoring systems to track progress and inform evidence-based action. Data and results should be shared transparently across stakeholder groups to build trust, accountability, and facilitate collaboration.
5. **Conduct regular reviews:** Regularly evaluate progress and community feedback to inform potential program revisions. As outlined above, program assessments should be conducted by an independent body and the results be made available to all stakeholders.

Finally, Climate Vault encourages the NSF to create a “Stakeholder Roadmap” for mCDR project developers. The Stakeholder Roadmap would help to educate project developers on the best practices for stakeholder identification and engagement, including many of the same steps outlined above, and provide them with the tools to successfully identify and engage with stakeholders at different stages of their technological maturity, including implementing test and pilot facilities or expanding their operations to new locations.

Thank you for the opportunity to provide feedback on the development of this important initiative. We appreciate your time and consideration and look forward to continuing the conversation as the mCDR Plan evolves.

Sincerely,

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Climate Vault



Climate Vault referenced the following sources in developing its RFI response:

Aspen Institute, Energy & Environment Program. “A Code of Conduct for Marine Carbon Dioxide Removal Research”. November 2023.

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