Terms of Reference and Strategic Plan for Ocean Visions Working Group

Advancing Research for a

Global multi-scale Ocean Carbon Observatory (GOCO)

https://oceanvisions.org/goco/

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Updated ***Oct 20, 2024***, prepared by Emanuele Di Lorenzo

Ocean Visions Working Group

Advancing Research for a

Global multi-scale Ocean Carbon Observatory (GOCO)

EXECUTIVE SUMMARY

This working group brings together institutions united by a shared long-term vision to establish an operational, multi-scale Global Ocean Carbon Observatory (GOCO). This observatory aims to play a pivotal role in tracking carbon dynamics, supporting the monitoring, reporting, and verification of carbon across various scales, understanding the impacts of natural and human-induced changes on ocean ecosystems, and fostering new scientific discoveries.

GOCO is an ambitious vision that demands resources beyond what a working group alone can provide. Recognizing this, the working group is committed to taking the initial steps toward its realization. Specifically, the group will:

1. Co-design and advance research and development to prototype building blocks addressing GOCO's infrastructure gaps, considering both technical and social dimensions.
2. Simultaneously engage global partners and organizations already working on observing marine carbon to collaboratively shape the design of GOCO, focusing on requirements for its operation, scalability, and long-term sustainability.

DURATION

An initial term of three years (2024-2027) with renewal is contingent upon progress and securing additional resources.

PARTNERING INSTITUTIONS

The list of institutions is updated as of ***October 5, 2024*** and will be expanded as new members join the WG (see **MEMBERSHIP CRITERIA**).

- Woods Hole Oceanographic Institution (WHOI)
- Stanford University (SU)
- Ocean Frontier Institute (OFI)
- Massachusetts Institute of Technology (MIT)

Ocean Visions Working Group

Advancing Research for a Global multi-scale Ocean Carbon Observatory (GOCO)

VISION

Establish a collaborative strategy to enable international research institutions to advance the research necessary for **co-designing** the **knowledge** and **governance frameworks** required to deploy and maintain a **Global multi-scale Ocean Carbon Observatory (GOCO)**. GOCO will build on the existing skeleton of sparse global carbon observing networks and will seek coordination through existing international organizations.

GOAL

Advance the understanding and monitoring of **marine carbon dynamics** and **perturbations**, including anthropogenic emissions and marine carbon dioxide removal (mCDR) with its Monitoring, Reporting, and Verification (MRV). This will allow for the evaluation of anthropogenic impacts on carbon flows, the development of innovative ocean-climate solutions, and the protection of marine ecosystems. The effort will be guided by a shared research agenda focused on sustainable observing infrastructure, numerical modeling, operational data systems, and the integration of governance and policy frameworks.

BACKGROUND & PURPOSE

Several international programs and organizations continue to develop and maintain core observing infrastructures for monitoring and understanding ocean carbon and biogeochemical cycles with sparse multi-scale coverage. A detail landscape analysis of these organizations is provided in this document Ocean Carbon Ecosystem Database. However, significant challenges still exist in advancing the research required for designing and scaling GOCO infrastructures both from the technical and societal dimensions (see **GUIDING RESEARCH QUESTIONS** section).

Research institutions are essential for advancing the research needed for GOCO, but they face significant challenges. Many of the scientific and technical gaps in designing and scaling GOCO's infrastructure require interdisciplinary collaboration that extends beyond individual institutions. Overcoming these barriers calls for strategies that enhance cooperation between

academic and non-academic research organizations, fostering innovation, resource sharing, and the exchange of expertise.

The GOCO Working Group (**WG**) is established to facilitate a collaboration among Ocean Visions' member institutions that aim at co-developing and executing demonstration projects and pilots that address the technical and societal research challenges of the **GOCO VISION and GOALS**.

The **WG is not intended to replace the efforts of international programs and organizations that are advancing sustainable marine carbon observation and providing coordination and convening platforms. Rather, the WG seeks to complement this work by establishing a strategy that enables research institutions to collaboratively address the critical research challenges and gaps that remain for realizing the broader goals of GOCO*.

GUIDING RESEARCH QUESTIONS

- **Baseline understanding:** How are nutrients supplied to the euphotic zone and how do these processes relate to the patchiness of plankton blooms, and their structure? What controls the size and efficacy of natural particle export events to the deep ocean, and how is this related to ecosystem structure? What controls how fast exported material remineralize in the deep ocean, and across constituents? What is the impact on subsurface carbon, oxygen and nutrient fields?

- **Drifting baseline:** How has ocean warming and acidification already changed ecosystems and carbon flows, and what will be their future trajectory? How will ocean carbon pumps change in future climate? How might a baseline for mCDR deployments be defined in areas that incur high biogeochemical and physical variability?

- **Environmental Impact**: What are the short-term and long-term environmental impacts of mCDR deployments on marine ecosystems? Investigating potential unintended consequences, such as impacts on marine biodiversity or water chemistry.

- **Efficacy Evaluation**: How effective are the mCDR technologies in capturing and sequestering carbon in different marine environments? What are the optimal conditions for maximizing carbon removal? How can we best determine optimal sites for the different methods?

- **Technology Assessment**: What are the technological challenges and limitations in MRV strategies required to support potential mCDR pilot tests? How can these MRV technologies be improved for enhanced performance, reliability, and scalability? The

focus is on refining the monitoring tools needed if and when mCDR trials are conducted, rather than advancing mCDR technologies themselves.

- **Scalability**: How scalable are the MRV frameworks being developed for potential future mCDR trials? What are the logistical, economic, and environmental considerations for scaling MRV systems? This question focuses on ensuring that MRV strategies can be effectively scaled to monitor and verify mCDR activities if deployed in the future.

- **MRV Capabilities**: How effective are the MRV approaches in accurately quantifying the amount of carbon removed? What level of accuracy and confidence is required for financing? What advancements are needed to improve the precision and reliability of MRV techniques?

- **Regulatory Compliance**: How do the mCDR and MRV approaches align with existing environmental regulations and international agreements? What are the regulatory barriers to implementation, and how might they be addressed?

- **Economic Viability**: What is the cost-effectiveness of the mCDR technologies tested? How do these costs compare to other carbon removal strategies?

- **Stakeholder Engagement**: How are stakeholders involved in the mCDR test pilots? What are their perceptions and concerns regarding the use of these technologies? How can stakeholders best engage with GOCO?

- **Policy Implications**: What frameworks/guidelines can be learned from other environmental industries (ie, wastewater, dumping etc.)? How could the outcomes of the test pilots inform policy and decision-making at local, national, and international levels? What policy frameworks are needed for MRV and mCDR?

- **Long-Term Monitoring:** What plans are in place for long-term monitoring and assessment of the deployed mCDR technologies? What opportunities are there to develop a blended finance model (public-private partnership) to sustain long-term ocean carbon monitoring to address commercial and regulatory needs? How will ongoing data be used to continuously improve the technologies and approaches?

- **Data Products:** What new data products are required to meet end-user needs across climate forecasting and monitoring, reporting, and verification of mCDR projects? How are data products designed from the outset for ease of uptake into ocean carbon system models?

OBJECTIVES

To advance **GOCO** and address the **GUIDING RESEARCH QUESTIONS**, the WG advances two initial parallel **THREADS** that are described below. These threads will be periodically updated to reflect the ongoing co-development of GOCO by member institutions and to allow for adjustments to the evolving international landscape of efforts in this area.

THREAD 1: Advance GOCO demonstration projects (2024-2027)

***Objective**: Leverage and enhance synergies among existing research investments within member institutions to initiate collaborations on pilot projects. These projects will focus on developing prototype demonstrations that address key gaps in GOCO's infrastructure, financing, and governance frameworks.*

Ongoing efforts among the member institutions (*updated* ***October 5, 2024***):

WHOI is leading the **Ocean Vital Signs Network (OVSN)** program, which aims at developing the innovations required to establish a high-resolution, full-depth observation network using advanced technologies to track carbon movement and monitor marine ecosystem health, enabling better understanding of ocean-climate dynamics and supporting scalable ocean-based climate solutions.

OFI is leading the **North Atlantic Carbon Observatory (NACO)**, a multinational platform to deliver comprehensive, sustained and integrated ocean carbon measurements to improve climate forecasts and support accountable measurements for mCDR. NACO will link intergovernmental agencies, industry, and research to deliver ocean carbon measurements at basin and climate-relevant scales by **facilitating** observation co-design with scientists, observation networks, and industry, **funding** ocean carbon observations with a sustainable blended finance business model, **operationalizing** robust and continuous observing and data infrastructure, and **delivering** standardized and integrated data products and scientific advisory services. NACO will work across existing ocean observing networks, ocean technology and data providers, and with end-users to leverage, enhance, expand, and integrate ocean carbon observations to deliver scientific integrity and data to inform critical ocean decision-making and effective climate change mitigation response for governments, industry and the public

MIT is spearheading a comprehensive **Climate Project**, inspired by President Sally Kornbluth, to become a leading source of climate solutions within a decade. This project fosters multidisciplinary collaborations, innovative projects, and includes a central Climate HQ with a significant focus on the the ocean's role in carbon dioxide and other greenhouse gas budgets, protecting natural carbon sinks and biodiversity, and integrating ocean health into urban planning.

Stanford is leading a project entitled **Developing robust MRV frameworks for mCDR**. The project aims to fill gaps in OAE MRV protocols for field experiments, which are essential for evaluating and scaling mCDR pathways, ensuring their effectiveness, and attracting necessary investments. The Stanford MRV/mCDR team is conducting a landscape assessment of the current status, gaps, and opportunities in the field of MRV for mCDR. Additionally, the team is exploring the feasibility of creating a pre-permitted test site in the North Pacific, equipped with sensors for mCDR monitoring, in collaboration with the Synchro network.

Under **THREAD 1** the WG will initially advance demonstration projects in the following areas:

- **Prototype carbon multi-scale tracking approaches**: Launch pilot projects to advance the technical and socio-economic infrastructure for tracking carbon across local, regional, and global scales. The OVSN will serve as the technical prototyping platform, with NACO functioning as the North Atlantic regional node and providing a blueprint for GOCO's global expansion. Though a Pacific regional testbed has yet to be established, we anticipate a future node in the North Pacific to complement NACO's role.

- **Advance robust MRV and mCDR assessment frameworks:** Facilitate collaboration across institutions to co-design and fund research projects focused on establishing baselines for carbon cycling and ecosystem health, and developing robust, consensus-driven MRV strategies. The focus is on preparing the necessary MRV frameworks that would support potential future mCDR trials, rather than advancing real-world mCDR experiments at this stage. The WG will build on Stanford's work on MRV frameworks for OAE in field experiments.

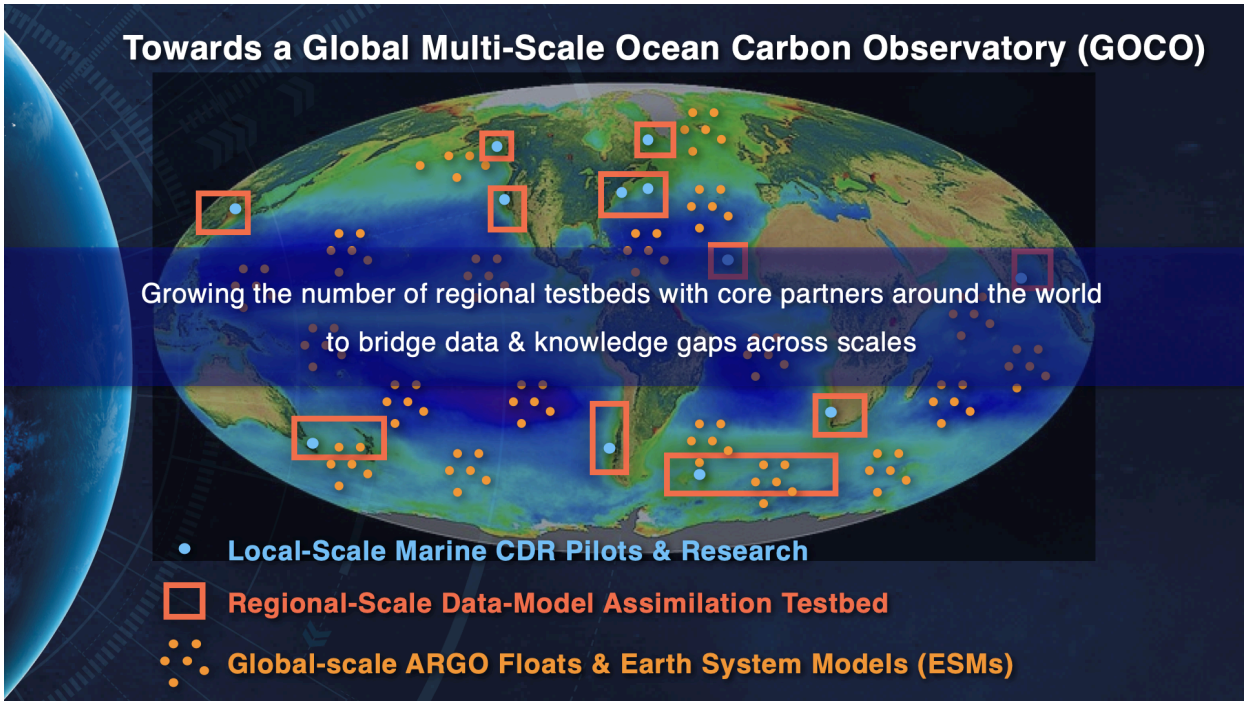
- **Develop prototype governance and finance frameworks:** Co-design projects to prototype sustainable governance and finance frameworks that can be demonstrated in regional nodes (e.g. NACO and in the North Pacific) to help scale to a GOCO network. The governance and finance frameworks are critical to ensure decision-making processes and long-term financial/operational sustainability of the initial investments in carbon observing infrastructure to deliver lasting research and climate outcomes.

If successful, the lessons learned from the OVSN and NACO frameworks (and others to be added from future members) will provide a blueprint for the science, innovation, governance, social engagement, and policy needed to further develop, fund, and operate the GOCO in other regions worldwide.

THREAD 2: Establish GOCO as a UN Ocean Decade Program (2025-2030)

Objective: *Objective: Provide member institutions with the flexibility to collaborate and co-design the future phases of GOCO alongside existing international programs and organizations without requiring an immediate commitment. While establishing GOCO as a UN Ocean Decade Program is an aspirational goal at this stage, it helps frame the purpose behind the institutions' collaboration and co-development efforts, positioning GOCO within a broader global context.*

OFI and WHOI have initiated preliminary discussions to develop a strategic plan that supports the long-term vision and goals of the Global multi-scale Ocean Carbon Observatory (GOCO). It is important to reiterate that Thread 2 is aspirational at this stage. The concept of evolving GOCO into a UN Ocean Decade Program serves primarily as a framework to initiate discussions with existing programs and international organizations (e.g., ARGO, GOOS, and others) that are already exploring scalable approaches to building a global network for multi-scale carbon monitoring and management. This concept outlines the direction for those conversations, providing a roadmap for potential collaboration. A landscape analysis of current efforts in this area is available in the document Ocean Carbon Ecosystem Database. Below is an overview of the GOCO program concept and a draft of its suggested objectives.



UN Ocean Decade Program "Concept"

Oceanographic and engineering research institutions partnering in this program are uniquely positioned to enhance the impact and reach of research aimed at ocean and climate solutions. Through a strategic collaboration framework, these institutions aim to leverage their

complementary strengths to address the challenges and risks associated with climate change and marine carbon dioxide removal (mCDR).

Hosted under the United Nations Decade of Ocean Science for Sustainable Development, this program seeks to pioneer transdisciplinary collaboration, research, and innovation. It focuses on the co-design and development of the knowledge, governance frameworks, and shared research agenda necessary to fund, deploy, and maintain the infrastructure for the Global multi-scale Ocean Carbon Observatory (GOCO). GOCO is essential for establishing a comprehensive baseline of the ocean's biogeochemical state. This baseline is critical for assessing the current climate state, projecting future climate scenarios, evaluating the effectiveness of mCDR strategies, and providing the data to help protect ecosystem services in the face of climate perturbations.

Objective 1: Co-designing a Framework for Ocean Carbon Knowledge & Data

- **Observation Design and Data Systems**: Develop comprehensive observation network designs and data systems, ensuring alignment with stakeholder needs.
- **International Engagement**: Engage with global research, industry, and government entities to design an inclusive observing system.
- **Standardization and Data Sharing**: Create and promote standardized protocols and platforms for data integration and dissemination.
- **Data Accessibility**: Guarantee open access and interoperability of data across institutions.
- **Innovation and Technology**: Encourage the development and adoption of advanced technologies for real-time monitoring and data analysis.

Objective 2: Co-designing a Framework for Ocean Carbon Governance

- **Governance Framework**: Establish a governance structure focused on transparency, accountability, and equitable data access.
- **Policy Development**: Develop policies for ethical data use, addressing privacy, intellectual property, and international cooperation.
- **Human Dimensions**: Incorporate social science research to explore stakeholder engagement, economic implications, and societal impacts.
- **Ocean Carbon Market**: Facilitate the development of a carbon market through reliable data for trading and credits.
- **Public-Private Partnerships**: Develop business models that leverage public and private partnerships for funding and sustaining operations.

Objective 3: Developing an Ecosystem of Institutions

- **Institutional Collaboration**: Establish a network of institutions supporting technical and social science dimensions.
- **Interdisciplinary Cooperation**: Foster transdisciplinary collaboration among natural scientists, social scientists, policymakers, and local communities.
- **Inclusive Approaches**: Ensure inclusive approaches in managing ocean carbon, considering diverse perspectives and needs.
- **Shared Research Agenda:** Develop a shared research agenda that aligns the efforts of participating institutions and stakeholders, ensuring a cohesive and coordinated approach to addressing ocean carbon challenges.

Under **THREAD 2** the WG will focus on the following efforts:

- **Enhance Interdisciplinary Collaboration**: Encourage cooperation between natural scientists, social scientists, policymakers, and stakeholders to address the multifaceted challenges of GOCO's ocean carbon monitoring and management goals.

- **Plan the expansion of GOCO**: Conduct conversations with existing international program and organizations to transition the insights from THREAD 1 into a broader, globally coordinated effort under the UN Ocean Decade Program, aimed at co-designing a scalable model for ocean carbon monitoring and management.

- **Secure Sustainable Resources**: Identify and pursue funding opportunities to support ongoing research and the establishment of GOCO initiative.

PARTNERSHIP AGREEMENT

To kick-start the long-term vision of GOCO and its regional nodes in the North Atlantic and North Pacific testbeds, institutions will formally collaborate on prototyping the GOCO infrastructure and launching demonstration projects under the existing **Ocean Visions Membership Agreement (Article II of the Constitution)**.

STRUCTURE & MEMBERSHIP CRITERIA

Initial structure for the GOCO WG

- **Conveners**:

    - Emanuele Di Lorenzo (Ocean Visions, WHOI)
    - Noah Gluschankoff (Stanford)
- **Co-Chairs**: 1 Chair and 3 Co-Chairs to be determined by ***November 30, 2024***
- **Member**: Representatives from partnering institutions: WHOI, OFI, MIT, and Stanford

Initial Members:

- Emanuele Di Lorenzo (Ocean Visions, WHOI), co-convener
- Noah Gluschankoff (Stanford), co-convener
- Rob Dunbar (Stanford)
- Bill Barnett (Stanford)
- Radhika Malpani (Stanford)
- Andrew Babbin (MIT)
- Tod Hynes (MIT)
- David Nicholson (WHOI)
- Susan E Wijffels (WHOI)
- Eric Siegel (OFI)
- Akash Rastogi (OFI)
- Anya Waite (OFI)
- David Koweek (Ocean Visions)

Criteria for New Members

New members from Ocean Visions institutions and beyond are encouraged to join, provided they can allocate resources to support the WG's activities and meet the following criteria to ensure active collaboration in advancing marine carbon research:

- **Active Institutional Investment:** Institutions must demonstrate ongoing investments in marine carbon research, such as investigating the potential of mCDR and MRV, with existing projects, research groups, or institutional support aligned with GOCO's goals.
- **Commitment of Resources:** Members must contribute resources to support joint efforts across institutions, including financial support for workshops, seed funding for researchers, or other resources that facilitate collaboration.

- **Engagement in Joint Projects:** Institutions must actively engage in the co-design and deployment of joint research projects, bringing their research teams together to achieve the collective goals of the WG.
- **Support for Education and Training Programs:** Institutions are expected to contribute to education programs by supporting postdocs and PhD students, through funding, mentorship, or providing resources that enable their active participation in GOCO-related projects.

Membership in the WG is designed to foster collaboration, ensure active participation, and leverage the strengths of each institution to achieve the shared goals of the GOCO initiative.

ACTIVITIES & DELIVERABLES

Workshops

- Workshop Schedule
    - **Winter 2025**, hosted by Stanford (funding already in place)
    - **Summer 2025**, hosted by WHOI (funding already in place)
    - **Winter 2025**, hosted by OFI (pending funding)
- Objectives
    - **map the combined research** strengths of our institutions
    - **target available funding opportunities** to advance joint research and innovation projects, and governance and finance models.
    - **draft initial terms of reference for a more long-term partnership** that clearly outlines a sustainable partnership model and milestones.
- Coordination and co-design
    - The WG will organize the workshops.

Demonstration Projects

- Institutions are committed to co-developing demonstration projects and building synergies across existing pilots. Specifically:
    - **WHOI** has deployed an initial set of OVSN Projects 2024-2025 (funding already in place)
    - **Stanford** is in the process of deploying some projects linked to the Sustainability Accelerator and the renewal of the MRV for mCDR team research.
    - The **MIT** Climate Project will begin designing Frontier Research Projects in Spring 2025 to advance its mission of “Restoring the Atmosphere, Protecting the Land and Oceans.”
    - **OFI** is convening a coalition of research organizations to collaborate on a Horizon Europe proposal to advance the governance framework and blended finance model to support sustained ocean observing infrastructure, such as NACO and GOCO.
    - **New Joint Projects.** The institutions are committed to developing new demonstration projects through the ideation workshops. Funding for the new projects will be identified as the projects are being designed.

Postdoctoral Program

Postdoctoral researchers at each institution will be engaged in various GOCO-related demonstration projects. The goal is to create a cohort of postdocs equipped with the interdisciplinary skills to navigate both the natural and social science aspects of GOCO. This cohort will foster cross-institutional collaboration and develop the next generation of leaders who can address the complex challenges in ocean carbon monitoring and governance. Various sources of support for the GOCO postdoctoral program have been identified:

- $3M funding available from combined sources at WHOI, OFI, and MIT
    - **MIT** & **WHOI** have $1M of ARPA-E support
    - **WHOI** & **OFI** have allocated $2M of institutional support
    - **Stanford** is considering allocating one or more of the Stanford Sustainability Accelerator Fellowships to the program

A subset of the WG will be formed into a mentor team that will provide overall guidance and coordination across the postdocs. If successful, the WG will plan identifying a recurrent sustain funding for a GOCO Postdoctoral Fellowship.

Websites

- Launch a dedicated OVSN website in Fall 2024 to document and share the WG's activities, findings, and progress.
- Launch a dedicated GOCO website in Fall 2025 to document and share the WG's activities, findings, and progress.

FUNDING

The participating institutions have committed funds to support the convening of the workshops, demonstration projects, and the postdoctoral program outlined in this proposal. Additional funding will be pursued jointly or in isolation by the institutions participating in the WG. These resources will ensure the successful execution of the WG's planned activities, including research collaboration, pilot projects, and the development of a global carbon tracking infrastructure.

GOVERNANCE

The GOCO WG will operate under the coordination structure provided by Ocean Visions, leveraging the organization's partnership arrangements to facilitate collaboration. The WG will adhere to an internal governance structure focused on transparency, accountability, and equitable access to data and resources. While Ocean Visions will provide assistance as possible and appropriate in co-designing the demonstration projects and supporting the activities of GOCO WG, institutions will retain full leadership and complete responsibility for advancing the WG's activities and projects. Ocean Visions will not contribute financial resources to the working group now, but reserves the right to do so in the future

RENEWAL & FUTURE DIRECTIONS

At the conclusion of the three-year term, the WG will evaluate its achievements, outcomes, and resource status. Based on this review, recommendations for renewal and further expansion of the GOCO initiative will be made, with the goal of establishing GOCO as a UN Ocean Decade Program.

NORMS & PRINCIPLES SHARED BY MEMBERS

Below is a set of norms and principles shared by the member institutions working together in this working group. This list will be periodically reviewed and updated as necessary, following the consensus of all WG member institutions. This list does not reflect the preferences of individuals serving on the WG but of the institutions they represent.

Commitment to Independent Research

Research on marine carbon dioxide removal (mCDR) strategies must be grounded in independent and transparent scientific inquiry. The efficacy, safety, and potential environmental impacts of mCDR approaches should be fully understood before any large-scale deployment is considered. Decisions on mCDR implementation should be guided by unbiased, science-based assessments.

Prioritizing Climate Action

Addressing climate change is an urgent priority, and significant reductions in carbon emissions must remain the immediate focus. While mCDR approaches may provide additional pathways to climate solutions, they must not detract from ongoing efforts to reduce emissions at the source.

Robust Observations and Monitoring

A comprehensive framework for monitoring, reporting, and verification (MRV) of both carbon

and environmental conditions must be established. These protocols are essential to assess the long-term effectiveness and safety of mCDR strategies. Monitoring should focus on ocean health, ecosystem impacts, and societal implications, ensuring data reliability and transparency.

Collaboration Across Sectors

An effective mCDR research program requires collaboration at national, regional, and global levels. Active partnerships among scientific institutions, governments, non-governmental organizations, and philanthropic groups are critical. Consensus-building and open communication will enhance the integrity and impact of research.

Ethical and Inclusive Research Practices

mCDR research must adhere to an ethical framework that promotes transparency, open data access, and stewardship of marine resources. Engagement with diverse partners, including Indigenous communities and other relevant rights holders, is essential to ensure the inclusive development of mCDR solutions. This inclusive approach fosters trust and equitable participation in the research process.

Field Trials and Testbeds

Before any large-scale deployment of mCDR technology is considered, robust MRV frameworks must be established to support future trials. The working group will focus on advancing the necessary MRV strategies and frameworks that will inform potential field trials. This will ensure that any future mCDR trials are conducted with the required monitoring systems in place. Community engagement should be prioritized when such trials occur, ensuring public awareness and involvement.

Focus on Science-Based Solutions

The working group does not endorse the premature deployment of mCDR technologies at solution-scale, as there remains insufficient data on their potential long-term impacts. The group remains dedicated to high-integrity research, ensuring that findings are freely accessible and that stakeholders from all sectors are involved in shaping future actions.

Long-Term Vision

The working group is committed to advancing the understanding of the ocean's role in climate mitigation through sustained excellence in science, engineering, and education. Research will be continuously applied to address pressing societal challenges and contribute to equitable climate solutions.

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