Carbon Direct

ADDENDUM TO THE 2024 EDITION

Criteria for High-Quality Marine Carbon Dioxide Removal

HYBRID

Abiotic marine carbon dioxide removal

Marine carbon dioxide removal (mCDR) pathways utilize the ocean's physical circulation, biogeochemical processes, and marine ecosystems to remove atmospheric CO_2 and durably store it in various forms. To safely deploy mCDR technologies and ensure precise carbon accounting, advanced forecasting and monitoring methodologies are essential, as these pathways both affect and rely on the dynamic ocean regime and marine life, including its intrinsic uncertainties. High-quality mCDR projects prioritize rigorous carbon measurement, monitoring, reporting, and verification (MRV) in addition to equally rigorous MRV of the ocean ecosystem and marine life (eMRV) to mitigate harm. The methodologies and protocols required for mCDR projects are under active development and are being continuously refined as new data emerges. Due to the emergent, high-stakes nature of this field, enhanced rigor is imperative, and the following criteria have been developed to reflect that standard.

Among the suite of mCDR pathways under development, this set of criteria focuses on the abiotic pathways of Ocean Alkalinity Enhancement (OAE), which captures and stores atmospheric CO_2 as bicarbonate dissolved in the ocean, and Direct Ocean Removal (DOR), which removes CO_2 from ocean waters and stores it externally. These methods offer the potential for durable, large-scale CO_2 removal in the coming decades.

The definitions of select technical terms used in these criteria are provided in the Glossary included at the end of this document.

Social harms, benefits, and environmental justice

These criteria build on and extend the social harms, benefits, and environmental justice considerations included under the "Essential principles for high-quality carbon dioxide removal" section of our *High-Quality Criteria for Carbon Dioxide Removal*.

PROJECT DEVELOPERS MUST

- Develop a social harms and benefits plan with consideration of potential impacts on fisheries, aquaculture, and existing coastal industries.
- Implement strategies for community engagement with consideration of preventing and addressing any misperceptions regarding potential risks associated with project activities.
- Minimize disruption of coastal businesses or those relying on the ocean.
- Ensure local traditional and Indigenous practices are not disrupted by project activities.

PROJECT DEVELOPERS SHOULD

- Actively engage with local communities and provide education on the regional ocean, ocean stewardship, and how project activities interact with the coastal and oceanic ecosystem.
- Address significant concerns from local communities, stakeholders, and fisheries through community education and, when appropriate, research and development with a third party or modifying the project plans prior to large-scale project implementation.
- Evaluate how project activities can improve existing climate and social inequities, including near major feedstock sources and processing facilities.
- Support local fisheries and aquaculture through partnerships involving co-benefits and profit sharing.
- Provide employment opportunities to local communities including those historically marginalized.

Environmental harms and benefits

These criteria build on and extend the environmental harms and benefits considerations included under the "Essential principles for high-quality carbon dioxide removal" section of our *High-Quality Criteria for Carbon Dioxide Removal*.

PROJECT DEVELOPERS MUST

- Develop eMRV protocols with consideration of the regional and relevant global oceanic regime, ecosystem health, all effluents discharged from project activities, and ecosystem responses.
- Implement strategies to mitigate potential harm caused by project activities.
- Monitor all effluents, site-specific reactions, and ecosystem responses from project activities, at clearly defined intervals on an ongoing basis.
- Develop and integrate specific eMRV plans for all keystone, vulnerable, sensitive, and endangered species that could be affected by project activities.
- Identify and define thresholds of harm for any changes to the oceanic regime and ecosystem caused by project activities.
- Implement plans for suspending project activities if the project causes harm or exceeds established thresholds. Include timely reporting and communication with local authorities and communities.
- Implement eMRV protocols for appropriate geospatial locations (e.g., depth) that span the project's duration and a defined period after project completion.
- Establish a baseline of the health of the marine ecosystem and relevant global and regional oceanic regime. Report all assumptions and uncertainties.
- Establish the baseline impacts on the marine ecosystem from all relevant pre-existing base facilities (e.g., desalination facility) processes, emissions, and disturbances, prior to project initiation.
- Use scientific studies, protocols, and monitoring methodologies to ensure sufficiently high accuracy (e.g., high-resolution ocean models, remote sensing, and autonomous platforms).
- Quantify and integrate inherent uncertainties into the eMRV plan.

- Assess potential impacts from project activities using available data and by conducting studies through an approved third party. Transparently share essential data relating to environmental impacts with the local community and broader scientific community.

PROJECT DEVELOPERS SHOULD

- Transparently share all data relating to the project with local communities and the broader scientific community.
- Use data from field trials and mesocosm studies to gather insights into potential large-scale impacts on and responses resulting from the project's activities.
- Evaluate and incorporate climate change impacts on the oceanic regime and ecosystem into assessments for establishing potential acceptable risk levels for project activities.
- Collaborate with local research institutions to advance studies on sustainable ocean management, eMRV methodologies, and the protection of marine food systems.
- Monitor all pre-existing base facility effluents, emissions, relevant site-specific reactions and disturbances at clearly defined intervals on an ongoing basis.
- Consult with pre-existing facilities and other relevant local industries to identify potential opportunities to increase the environmental safety of external processes.

Additionality and baselines

These criteria build on and extend the additionality and baselines considerations included under the "Essential principles for high-quality carbon dioxide removal" section of our *High-Quality Criteria for Carbon Dioxide Removal*.

PROJECT DEVELOPERS MUST

- Establish a baseline of the relevant oceanic regime through historical data and monitoring methodologies that includes variability ranges, significant outlier events, and inherent uncertainties. Document and transparently share assumptions and uncertainties.
- Establish relevant baseline data for all pre-existing base facilities and processes, prior to initiating the project.

Measurement, monitoring, reporting, and verification

These criteria build on and extend the measurement and MRV considerations included under the "Essential principles for high-quality carbon dioxide removal" section of our *High-Quality Criteria for Carbon Dioxide Removal*.

PROJECT DEVELOPERS MUST

- Conduct a life-cycle assessment (LCA) with consideration of processes such as mineral dissolution and gas exchange.
- Use high-quality monitoring methodologies to quantify CDR and report assumptions and uncertainties.
- Identify conservative upper and lower bounds of the project's anticipated CDR volumes within a specific time frame for quantification of an uncertainty budget.
- Assess and incorporate data variability and inherent uncertainties into the baseline.
- Implement an MRV plan that includes region-specific and relevant global processes, accounting for ocean circulation and biogeochemical cycles.
- Regularly update the project's MRV plan to incorporate the best available science and monitoring tools and techniques.
- Directly monitor the relevant properties and chemical composition of project feedstocks, products, intermediates, and by-products. Predict and assess any potential responses upon discharge into seawater that could impact the project's CDR efficacy.
- Ensure proper carbon accounting for all end uses and fates of captured CO_2 to avoid double counting.

PROJECT DEVELOPERS SHOULD

- Use energy with low associated emissions and provide the electricity emissions factor and the latest emissions factor for the local electrical grid if purchasing electricity from the grid. The use of marginal emissions factors may be appropriate, depending on grid conditions.

Durability

These criteria build on and extend the durability considerations included under the "Essential principles for high-quality carbon dioxide removal" section of our *High-Quality Criteria for Carbon Dioxide Removal*.

PROJECT DEVELOPERS MUST

- Predict and monitor relevant global and regional changes to the oceanic regime that pose a risk of releasing carbon stored within the ocean.
- Regularly update durability calculations with project data and the latest scientific research.
- Implement long-term plans for specifically monitoring the durability of captured CO_2 well after project completion. Transparently share relevant data with the scientific community.
- Monitor for conditions and processes, at all relevant points in the project's facility, that could result in CO_2 outgassing and/or secondary carbonate precipitation.
- Disclose the biogeochemical model used to predict the fate of the captured CO_2.
- Disclose the use of CO_2 as a feedstock, and the risk of CO_2 reversal from any non-durable product or commodity.
- Follow guidance set forth for durability of direct air capture in the *High-Quality Criteria for Carbon Dioxide Removal* when storing pure CO_2 (e.g., as in DOR projects).

PROJECT DEVELOPERS SHOULD

- Seek long-term monitoring solutions for storage, such as through regulatory takeover as envisioned by the European Union Carbon Capture and Storage Directive.

Leakage

These criteria build on and extend the leakage considerations included under the "Essential principles for high-quality carbon dioxide removal" section of our *High-Quality Criteria for Carbon Dioxide Removal*.

PROJECT DEVELOPERS MUST

- Predict, monitor, and report changes in the oceanic regime, regionally and globally, that could result in the release of CO_2 or unfavorably impact the carbon cycle elsewhere.

- Monitor and mitigate disruptions to local coastal businesses or those relying on the ocean in a way that could lead to increased emissions outside the project boundary, including land-based and maritime activities.
- Account for energy use induced by project activities and evaluate potential leakage from (1) upstream and downstream use of fossil-fuel energy sources and (2) electricity powering operations, including grid-related emissions from power purchase and use.
- Account for the counterfactual use of feedstocks and any increased production demand induced by consuming those feedstocks for project activities.

Other considerations

Permits and Law

PROJECT DEVELOPERS MUST

- Conduct the project in accordance with all applicable regional, national, and international laws, regulations, and best practices for ocean-based activities that are not necessarily legally binding.
- Adhere to any applicable regulations from the London Convention and London Protocol regarding marine geoengineering activities and any non-coastal discharge into the ocean, the principles laid out in the United Nations Convention on the Law of the Sea (even if the host country has not ratified it), maritime zone regulations, regulations on exploitation of ocean resources, exclusive economic zones, and high seas boundaries and use rights.
- Mitigate negative impacts on international maritime activities.
- Consult with relevant agencies regarding all applicable coastal zone management plans, new or existing permits, and certifications.
- Engage in public comment periods and stakeholder consultations as part of the permitting process.

PROJECT DEVELOPERS SHOULD

- Work with national and international governmental bodies to cooperatively share relevant information and establish clear, sustainable, and equitable governance for the deployment of mCDR.
- Demonstrate consistency with coastal zone management plans of adjacent coastal states, where applicable.
- Assess project compliance with evolving governance frameworks, including the potential impact of the new Agreement on Marine Biodiversity of Areas beyond National Jurisdiction (BBNJ Agreement) for activities in international waters.
- Consult with local permitting agencies and identify any areas where the project should go above and beyond requirements to mitigate environmental harm and ensure the durability of mCDR.

Scalability

PROJECT DEVELOPERS MUST

- Evaluate and incorporate any necessary adjustments to the eMRV and MRV plan that may result from increasing the scale of the mCDR project, such as a decrease in the signal-to-noise ratio and increased uncertainty.
- Predict and mitigate potential social and environmental harms and benefits associated with increasing the scale of the project, including those linked to increased feedstock consumption.
- Predict and evaluate the potential impacts of halting project operations (at scale) to the environment and durability of stored carbon.
- Develop plans to stop project operations if ecosystem harm is detected or harmful thresholds are exceeded. Incorporate a risk assessment of termination shock and a remediation strategy for the project at anticipated scales.
- Follow the guidance set forth in this document for scalability of direct air capture when applicable.

Glossary of technical terms

Environmental monitoring, reporting and verification (eMRV): refers to rigorously predicting and monitoring all potential acute, chronic, and cumulative impacts of project activities on the oceanic regime and the health of the ecosystem.

Inherent uncertainty: refers to the inherent uncertainties related to the oceanic regime, monitoring methodologies, and biogeochemical responses.

Monitoring methodology: refers to all techniques used for predicting and monitoring the oceanic regime. This includes ocean modeling, in-field observation:

- **In-field observation:** refers to monitoring the oceanic regime and ecosystem in the field, such as marine life observation, remote sensing, autonomous platforms, and analytical techniques for in-field and offshore seawater sampling and analysis, including quality assurance and quality control processes.
- **Ocean modeling:** refers to numerical modeling relevant to mCDR, including ocean biogeochemistry and physical processes.

Oceanic ecosystem: refers to the interaction between living and non-living components within marine environments. This includes all marine life and their interconnected relationships such as community responses and biodiversity:

- **Marine life:** refers to all living organisms in the ocean, through the food chain, and species directly dependent on the ocean (e.g., migration patterns of birds).

Oceanic regime: refers to all conditions and processes of the oceans. This includes ocean biogeochemistry and circulation:

- **Ocean biogeochemistry:** refers to the processes and interactions that regulate the cycling of elements in the ocean. This includes all parameters and processes that pertain to marine life (e.g., photosynthetic processes and biogenic calcification), all mechanisms that relate to sedimentation at the sea floor, and all physical and chemical properties and processes within the ocean (e.g., nutrient cycling and air-sea-gas exchange).
- **Ocean circulation:** refers to all movement of ocean water.

Social harms and benefits plan: refers to monitoring potential acute, chronic, and cumulative positive and negative impacts on the local and marginalized communities resulting from project activities. These may include impacts on livelihood, and health and well-being.

- **Community engagement:** refers to informing and engaging with local communities regarding project activities and their potential harms and benefits in a way that is open, honest, and clear. This includes, but is not limited to, general outreach, educational offerings, and training opportunities.
- **Local communities:** refers to stakeholders and communities (including Indigenous communities) proximate to and affected by the project activities.
- **Marginalized groups:** refers to groups that have been disadvantaged or excluded from certain social, economic, political and/or cultural pursuits. This often includes low-income communities, communities of color, Indigenous communities and or other groups on the frontlines of the climate crisis and racial/economic injustice.

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This document is an addendum to the fourth edition of the *Criteria for High-Quality Carbon Dioxide Removal*, which stands as a testament to the collaborative spirit and deep expertise of over 50 science contributors from Carbon Direct, Microsoft, and independent reviewers across industry and academia. The specialized knowledge and commitment of our contributors is the cornerstone of this edition, providing wide-ranging expertise in a range of fields from engineering and project implementation to ecology and climate justice. We also acknowledge the valuable support provided by our management, marketing, legal, editorial, and design teams. These contributions significantly enhanced the clarity, accessibility, and impact of our work. We extend our deepest gratitude to all who have played a part in bringing this edition to fruition.