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Precautionary Principles for Ocean Carbon Dioxide Removal Research

Virtually all future climate scenarios that hold planetary warming close to 1.5°C by 2050 will require massive cuts in greenhouse gas emissions, supplemented by the use of carbon dioxide removal (CDR) to remove leftover heat-trapping carbon dioxide (CO_2) from the atmosphere.[1] The ocean has already naturally absorbed 26% percent of all CO2 emissions caused by humans between 1850 and 2021,[2] and many people are interested in deliberately increasing this uptake using ocean CDR –also called marine CDR.

Taking swift action to address climate change and meet Paris Agreement goals is essential to avoid even more catastrophic impacts of climate change. But it is also imperative to safeguard the ocean's existing ability to absorb and store CO_2, which has dampened the effects of global warming so far and regulates the Earth's carbon cycle, and to sustain the multitude of ways the ocean supports natural and human systems.

It's important to note that other climate intervention methods, not just ocean CDR, would affect the ocean. Even though research on most of these large-scale activities to counteract anthropogenic climate change and its impacts is just beginning, it is clear that climate interventions, including ocean CDR, cannot substitute for deep emissions cuts or adaptation.[3]

More research is needed to understand the climate mitigation potential plus the environmental and social impacts of different ocean CDR approaches.

The threat of climate change necessitates serious consideration of a wide suite of solutions, including ocean-based CDR strategies. Many unknowns remain about the effectiveness, outcomes, benefits, and risks of ocean CDR approaches, most of which have not been thoroughly researched. For instance, the ocean is the planet's largest carbon reservoir, but whether its carbon storage can continue to increase is uncertain. Also, some types of ocean CDR research may negatively affect marine ecosystems, habitats, and human communities, while others may be lower risk or be associated with ecological co-benefits. The current patchwork of ocean laws and regulations do not specifically apply to ocean CDR,[4] and many additional questions remain open about oversight, safety standards, equity, ethics and responsibilities. There is also no clear and consistent path towards permitting research activities, but these will increasingly involve larger-scale experiments in the ocean.

Widespread, publicly supported research on ocean CDR is needed to ensure transparency and to minimize bias. Well-planned, deliberate, hypothesis-driven research is essential to close existing knowledge gaps, and better understand the socio-economic, environmental, ethical,

CAP
OA Alliance — International Alliance to Combat Ocean Acidification
AGU — Advancing Earth and Space Science
PML Plymouth Marine Laboratory
National Wildlife Federation
The Ocean Foundation
Ocean Conservancy
Environmental Defense Fund
NRDC

and justice considerations. Only such comprehensive research can inform decision making about ocean CDR approaches and their application.

Few ocean CDR methods are ready for deployment at scale today.

Many ocean CDR approaches have only been tested in the laboratory, in situ at small scales, or in computer models. These "concept stage" methods[5] include cultivation of phytoplankton biomass or macroalgae (seaweed) for various end uses (e.g., burial on land or at sea); enhancing coastal weathering and ocean alkalinity; and ocean iron fertilization.[4] It is a substantial leap to confirm that an ocean CDR approach understood at the concept stage is safe for deployment at scale in the marine environment. Therefore, research efforts need to be ramped up to identify ocean CDR approaches that appear to be environmentally and socially safe and effective candidates for development.

Other ocean interventions constitute "low regret" carbon removal actions[5] that pose few risks and offer numerous non-carbon-cycle benefits in addition to storing carbon.[6] These include conservation and restoration of mangroves, seagrasses, kelp forests, marine mammals and fish; limiting disturbance of carbon-rich environments, including seabeds; and growing seaweed sustainably to produce food, colloids, and other products that have potential to store carbon, replace GHG-intensive products like plastics, or suppress GHG emissions (but several of these strategies will require additional research).[4,7–9] Questions remain especially about how much additional carbon these approaches remove (i.e., how much their carbon storage can be enhanced) and how durable the removal is.[10–12] Hence, while much of the focus on nature-based interventions has been about "blue carbon," the major benefit from conserving and restoring some of these systems may actually come from other services they provide or from shielding them from destruction (because uprooting blue carbon systems releases additional greenhouse gases).

While some ocean CDR approaches show promise, none have yet been shown to empirically increase ocean uptake of atmospheric CO_2, for long periods of time, and without significant downsides.[4,5] Furthermore, technology and methods to monitor and verify carbon dioxide removal are still being developed. Ideally, carefully designed research will uncover whether any ocean CDR approaches occupy this "sweet spot" of verified, durable carbon removal with minimized risks to environments and social systems.

Principled ocean CDR research will help safeguard ocean systems.

Interdisciplinary research that addresses the urgent need for climate solutions while also protecting the ocean's natural functions must incorporate three principles:

Community engagement is essential. People whose activities and interests may be affected during research or any larger-scale deployment must be included and consulted in research activities, including research development. This is essential to ensure maximum benefits and minimize harm, especially for vulnerable populations or historically marginalized communities. Engagement should be guided by principles of free, prior, informed consent (FPIC).

Open and transparent communication and information sharing are fundamental. Both private and public entities conducting ocean CDR research must operate and share information in a highly transparent, factual, collaborative way, particularly so that affected people can make evidence-based decisions about these approaches that account for unintended outcomes.

Approaches must robustly verify carbon removal. Scaling up any ocean CDR approach for research or eventual deployment must be guided by evidence about the durability, verifiability, and additionality of its carbon removal effect as much as its environmental and social safety.

Precautionary, inclusive, and well-planned ocean CDR research must be conducted to ensure these technologies can benefit the climate without harming the environment and people.

Research on ocean CDR is required to understand the full spectrum of potential climate solutions. But the research must be precautionary, inclusive, and well-planned to avoid harm to environmental and social systems. It must also explore socio-economic and environmental trade-offs, ethical and environmental justice considerations, and governance structures and needs. This research may occur at public, private, or governmental institutions. Specific actions can help researchers achieve these multiple objectives:

● Adopt an enforceable research code of conduct. Numerous groups have called for or have begun developing an ocean CDR research code of conduct applicable in all locations to help embed transparency, accountability, equity and inclusion into ocean CDR research. An ocean CDR research code of conduct would help assure people not involved in the research that trials have been designed to minimize risks and develop research results for the public good. A code of conduct should:

○ require all researchers to assess and minimize potential adverse effects of experiments on the marine environment and human communities prior to research and report actual effects during and after research;

○ require researchers to engage meaningfully with stakeholders and frontline communities, with particular attention to vulnerable populations, prior to conducting field experiments; and

○ establish principles of responsible research including funding transparency, peer review, and the publication of results.

● Carry out multidisciplinary ocean CDR research. Decision making about ocean CDR research and deployment will be influenced by community priorities, values, goals, and competing interests. Research that seeks to understand not only ocean CDR approaches but also the social considerations surrounding their use and their environmental impacts will provide information relevant for current and future ocean CDR decision making.

● Clearly distinguish research from deployment. Performing field trials of ocean CDR in ocean systems could be seen as a "slippery slope" to poorly regulated or rash deployment of unproven technologies. Research field trials seek to investigate the safety and efficacy of ocean CDR technologies. Only after an approach has demonstrated repeatable, durable, and additional carbon sequestration can an approach be considered for incorporation into carbon markets.

● Ensure ocean CDR research is hypothesis-driven. Even though ocean CDR research is likely to advance knowledge about the carbon cycle and marine systems, research should always be grounded in hypotheses that are specifically relevant to CDR, such as magnitude or permanence of removal or effects of interventions on nearby surroundings.

● Establish rigorous, standardized monitoring, reporting and verification (MRV) procedures. The variability in the natural ocean carbon cycle poses significant challenges to MRV of carbon removal via ocean CDR. Rigorous, data-based MRV procedures should be established by government agencies (e.g., NOAA in the US) and adopted in all ocean CDR research. These MRV procedures will need to be updated periodically as knowledge and needs evolve.

● Define spatial and temporal goals before beginning research. Large scale efforts seeking to remove CO2 from the atmosphere measurably would be slower to achieve. Smaller scale approaches could more quickly cause detectable localized, transitory remediation of ocean acidification, carbon sequestration, greenhouse gas emissions, and other benefits.

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