Navigating the sea of uncertainty around Marine Carbon Dioxide Removal (MCDR)

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Emily Warrender

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Prof. Christopher Pearce and Dr Willem van Dorp discuss the need for science-based governance approaches when evaluating the potential benefits, impacts and effectiveness of emerging marine carbon dioxide removal techniques

A range of new techniques are currently being explored that seek to extract and permanently store atmospheric carbon dioxide (CO_2) in the ocean. The anticipated scalability of these approaches has driven rapid growth in the still-emerging sector, with the first independently verified marine carbon credits being sold earlier this year.

Yet the potential effectiveness and impacts of manipulating marine processes in this manner remain highly uncertain; thus, the development and implementation of science-based governance frameworks is critical for understanding if, where and how such techniques might be applied in our fight against climate change.

Carbon dioxide removal is now essential

There is no doubt that the planet is warming or that slight increases in global temperature can drive significant variations in weather patterns with catastrophic consequences for human populations and natural ecosystems. There is also no doubt that the emission of greenhouse gases such as CO_2 into the atmosphere through human activities is the chief culprit in driving this rapid rise in temperature.

Ending these emissions is essential if we are to limit the extent of warming to <2oC in line with the Paris Agreement. However, even the most ambitious Net Zero targets cannot achieve climate neutrality solely through green technologies and clean energy. Actively removing CO_2 from the atmosphere has consequently become an integral requirement of all Net Zero pathways, prompting a scientific race against time to find approaches that can sustainably, durably, and safely capture and store CO_2.[1]

Currently, most carbon dioxide removal (CDR) occurs on land using conventional, well-established approaches, such as afforestation/reforestation, and through land-use management techniques like peatland restoration and soil carbon sequestration.

More novel land-based techniques, including direct air carbon capture and storage (DACCS), bioenergy with carbon capture and storage (BECCS), enhanced rock weathering (ERW) and biochar, are also starting to be implemented at commercial scales and are projected to constitute the majority of proposed CDR contributions by the middle of the century.

Exploring marine carbon dioxide removal

Whilst ocean-based marine (m)CDR approaches are typically less developed than their terrestrial counterparts, their inferred applicability across large portions of Earth's surface, coupled with significant gaps in the amount of CDR required to meet Paris climate targets, has driven a rapid rise in interest in mCDR techniques.[2,3]

In general terms, mCDR approaches seek to increase the absorption of atmospheric CO_2 into seawater by stimulating, duplicating or imitating the biological or chemical processes that already enable the oceans to naturally take up ~10Gt CO_2/yr.[4,5]

Biological approaches, such as ocean fertilisation and biomass sinking, rely on the absorption of dissolved CO_2 into marine phytoplankton or macroalgae (seaweed) through photosynthesis, with enhanced rates of production, export, and preservation of organic matter, minimising the return of the trapped carbon back to the atmosphere.

Chemical approaches such as ocean alkalinity enhancement (OAE) and direct ocean carbon capture and storage (DOCCS) increase the flux of CO_2 into seawater by either adding alkalinity to neutralise the acidity of the ocean (lowering the amount of CO_2 dissolved in seawater) or extracting CO_2 directly through ex-situ processing, with subsequent utilisation or storage of the purified CO_2 gas.

Other conceptual mCDR techniques include artificial downwelling, which aims to physically transport carbon-rich surface waters into deep-sea settings. Marine environments can also be used to store CO_2 captured elsewhere (e.g., through terrestrial biomass deposition and the mineralisation of the oceanic crust), although such approaches are generally not classified as mCDR as they do not increase the absorption of CO_2 into seawater.

What do we need to consider?

While the underlying scientific processes are well understood, the cost, impacts and trade-offs associated with conducting mCDR at commercially and climatically relevant scales remain less certain.[2]

Our ability to monitor the net extent of atmospheric CO_2 removal in open-ocean settings remains a critical challenge, and the potential ecological and environmental risks or co-benefits of conducting and upscaling mCDR approaches remain largely unknown.

Resolving these uncertainties, as well as other technical considerations such as energy and material demands, requires the implementation of small-scale, controlled, and transparent pilot studies.[6,7] Such in-situ assessments are starting to be conducted – often led by the commercial entities wishing to upscale the approaches – and are highlighting gaps and differences in mCDR regulatory guidelines, with the extent and nature of governance requirements varying significantly between nations.[2]

Some explicit guidance is provided at the international level through the London Convention and the London Protocol; however, the relevant amendments have yet to come into force and are not legally binding. Advancing the potential for responsible mCDR implementation consequently requires the development of more robust national and international governance frameworks, in addition to an improved understanding of public perception towards the different technologies and their potential social impacts. [2,3]

Enabling responsible and transparent evaluation

Addressing these needs, the Strategies for the Evaluation and Assessment of Ocean-based CDR (SEAO2-CDR) project is currently integrating scientific, social, legal and commercial knowledge to develop the tools, mechanisms and guidelines required to ensure that mCDR techniques can be developed in a responsible and transparent manner.

Through three core themes, the project is:

1. Characterising the key system boundaries, processes, material and energy flows of different mCDR approaches and evaluating their temporal and spatial monitoring requirements and mechanisms.
2. Establishing the social, regulatory, political, economic and ethical frameworks required to support mCDR uptake at scale.
3. Enhancing our understanding of realistic implementation policies and pathways via an integrated assessment of system-level effects.

Key advancements made in each of these areas will be highlighted through a series of forthcoming articles in Open Access Government, alongside other recommendations and priorities, to enable informed decision-making regarding whether, where, and how mCDR techniques might be deployed as part of a balanced climate change mitigation approach in the future.

References

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Project

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Primary Contributor

Christopher Pearce
National Oceanography Centre
ORCID: 0000-0002-4382-2341
Additional Contributor(s)

Willem F. van Dorp
Uniresearch B.V.