Biological methods

Artificial upwelling: More power for the ocean's biological carbon pump

Algae, zooplankton and fish are among the key players in the biological carbon pump that allows the ocean to naturally remove carbon dioxide from the atmosphere and store it at great depths. However, for this mechanism to function optimally, it needs nutrients, which are lacking in many places, at least in the light-flooded surface water. By pumping up nutrient-rich deep water, humans could remedy this nutrient deficiency. But whether artificial upwelling would actually have an effect on the climate, what risks it would entail and whether it could be technically and legally implemented on a large scale, is still uncertain. The research mission CDRmare provides

The big climate goal: A net zero of carbon dioxide emissions

- There is a consensus in climate research: even with ambitious climate policies, humanity will still be emitting **10 to 20 percent** of current carbon dioxide emissions by the middle of the 21st century and thus continue to drive global warming.
- To compensate for these residual emissions, humankind will either have to capture carbon dioxide directly at its source or remove it from the atmosphere to the same extent.

Increased algae growth, enhanced transport of biomass into the deep ocean

- An **increased carbon dioxide removal** could also be achieved with the help of the sea, for example, by **increasing the biological carbon pump** in formerly less productive marine regions. This would mean increased algae growth in surface waters. After the death of the algae, its carbon-rich biomass would either sink directly or migrate through the food web and via this by-pass be transported into greater depths – not completely, however, but only to a certain extent.

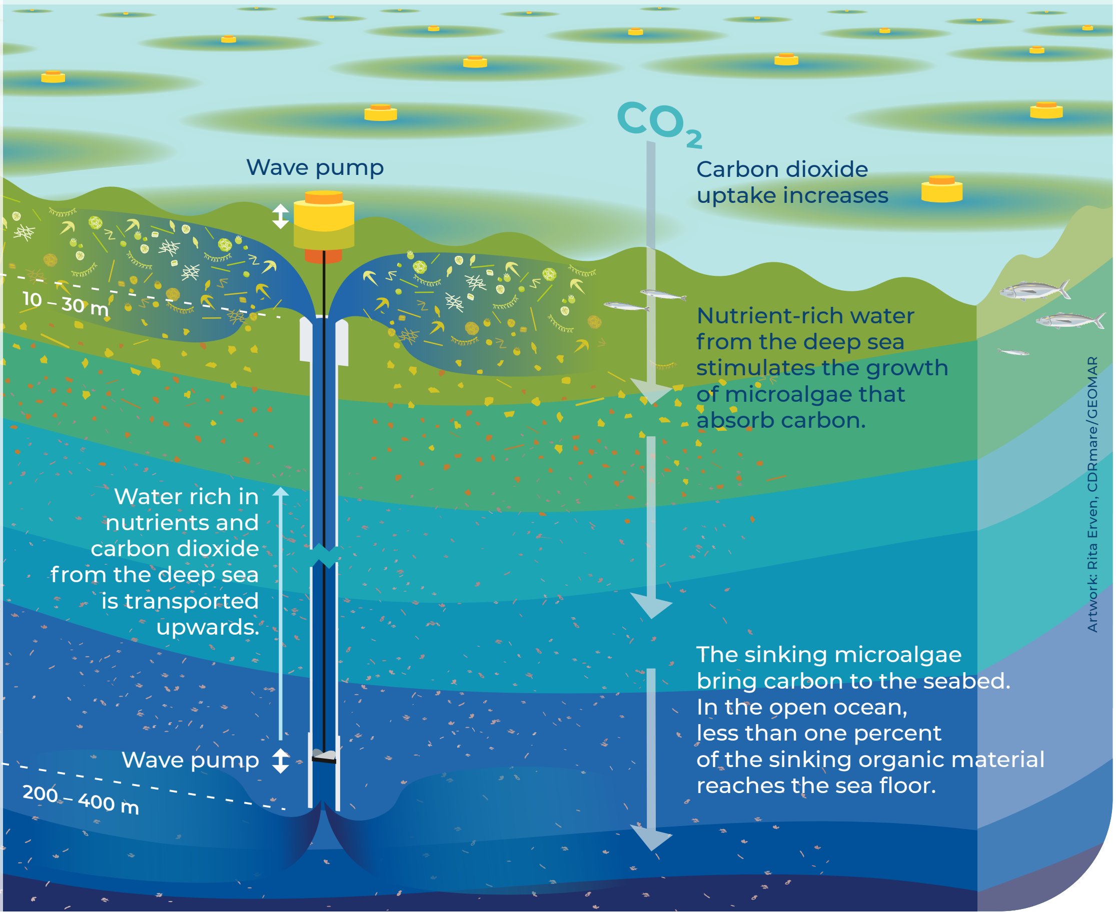
Artificial upwelling

Costs:
So far not quantifiable. Initial calculations take place within CDRmare.

Scalability: **Carbon dioxide storage on a larger scale is theoretically possible;** upwelling pumps could be used both **in the marginal seas and on the open ocean.**

Duration of storage: **for decades to centuries.**

Technical state of development:
in the early stages



- At great water depths, **the carbon contained in the biomass and possible degradation products would be trapped for decades, at best for centuries**, and would not be able to escape into the atmosphere in the form of carbon dioxide.

Artificial upwelling: Fertilizer from the deep ocean

- **Nutrients are the limiting factor** of the biological carbon pump. Where they are lacking in the surface water biomass production and thus carbon dioxide uptake by algae comes to a standstill. By **pumping up nutrient-rich deep water**, less productive oceanic regions could be supplied with sufficient nutrients.
- This approach is referred to as **artificial upwelling** because it mimics the functionality of natural upwelling areas off the west coasts of Peru, Namibia, California and Mauritania. These areas are among the most productive and fish-rich marine regions in the world. However, to achieve the same upwelling effect, **tens of thousands of upwelling pumps** would have to be operated in nutrient-poor oceanic regions.

Trial run: Testing of an optimised upwelling pump in the open ocean

- As cold, carbon dioxide-rich deep water rises to the ocean surface, it warms, which can cause **carbon dioxide to escape from the ocean into the atmosphere**. Such outgassing would reduce the climate effectiveness of artificial upwelling processes. However, the results of the research mission CDRmare suggest that, under certain circumstances, such methods have a **higher carbon dioxide removal potential** than previously thought. However, the extent to which this potential can be realised is still uncertain.
- In the research mission CDRmare, scientists for the first time conduct **comprehensive, transdisciplinary studies on the technical, ecological, biogeochemical, economic and legal and legal feasibility of artificial upwelling**. This also includes the test run of a **newly developed seaworthy wave pump** off the coast of Gran Canaria.

Extensive interdisciplinary research

- The development and test run of the upwelling pump will be accompanied by extensive **simulations of optimised flow models**, which are used to understand the basic biogeochemical processes of upwelling nutrient-rich deep water. At the same time, biologists conduct diverse experiments to test the **responses of algae and zooplankton to the increased nutrient supply** and their optimal growth- and adaptation-potential are investigated.
- In parallel, economists develop an integrated assessment model that can be used to assess the **economic and climate policy benefits of artificial upwelling**.
- Legal scholars examine the existing legal framework for such an operation and to find out which changes to the legal conventions and principles would need to be made to create an **adequate regulatory framework for the management of artificial upwelling**.

CDRmare delivers answers

- Based on the several analyses, the researchers will compile **options for action for decision-making in politics, businesses and society**. This knowledge will enable all stakeholders to make **fact-based** decisions about the benefits and risks of a possible use of artificial upwelling to increase the ocean's carbon dioxide uptake.

All research activities described here are carried out within the CDRmare consortium »Test-ArtUp – Road testing ocean artificial upwelling«.

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