

Carbon dioxide removal from the atmosphere using sustainable energy

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Lab-scale setup for capturing CO₂ from seawater. Through the transparent module in the center, where green square seals and brown membranes are visible, (artificial) seawater containing CO₂ flows, and the pH is successively lowered and raised, allowing the CO₂ to be separated. Surrounding this module are pumps, regulating valves, pH meters, and a power source to keep this process going and to accurately monitor it. Credit: TU Delft/Rose Sharifian

Much work is taking place on methods for capturing CO₂ from the atmosphere to combat climate change. In addition to existing methods that use toxic solvents, electrochemical techniques that can work with sustainable electricity are now becoming available. The TU Delft research group led by David Vermaas worked together with Wetsus and Caltech to analyze these sustainable technologies for CO₂ removal, and compared them for the first time. The researchers also described which methods show the most potential for making large-scale CO₂ removal possible. Their paper on this was published recently in the scientific journal *Energy & Environmental Science*.

It sounds like an ideal solution to combat climate change, but CO₂ removal is really not so easy. There are various circumstances under which CO₂ can be captured. It can take place directly at a large source of CO₂, but it is also important to be able to capture CO₂ from decentralized emission point sources. Researcher David Vermaas explains: "Ultimately, power plants and industry are only responsible for a certain proportion of carbon emissions. Decentralized sources, such as cars, agricultural industries, heating and aircraft together account for 40% of CO₂ emissions in the atmosphere."

Electrochemical routes

Methods have been developed for both centralized and decentralized capture, but for decentralized capture in particular, there are few energy-efficient, clean methods available. A possible solution is provided by what are known as electrochemical routes, which enable the pH of a solution to be adapted and the CO₂ to be concentrated. Laboratory tests have proved that these techniques are effective and work on the basis of electricity rather than heat. Here the CO₂ is converted into carbonate or bicarbonate salts, and then concentrated as pure CO₂ or limestone.

Vermaas's research group has now compared the various electrochemical

methods for the first time, and studied their feasibility. Their studies showed that for all the methods, the energy required forms a barrier. Vermaas: "In theory not much energy is required to convert CO₂ into another form of carbonate or bicarbonate, but right now the current methods are not efficient enough. On average 50% more energy is used than is needed in a theoretical conversion." The relatively low concentration of CO₂ in the atmosphere means it has proved particularly difficult to use it as feedstock for the conversion reaction.

Ocean as a buffer

Vermaas and his colleagues are using their analysis to steer the direction of future research. One option that shows great potential is capturing CO₂ from the ocean. Vermaas states, "The ocean acts as a huge buffer absorbing large amounts of CO₂ from the atmosphere every year, and that makes this the ultimate way to capture CO₂ from decentralized sources." We could adapt existing desalination plants, so that in the future they can also remove CO₂ from seawater. This concept based on acids and bases has become more feasible and energy-efficient in recent times through the use of membranes with improved conductivity and improved electrochemical cell designs. An additional benefit is that this technique prevents lime scale deposits in the desalination plants.

Vermaas's research group is already working on developing the technology in which the CO₂ in the water is converted into either pure CO₂ gas or calcium carbonate. Working on a scale of 10 cm, they have already succeeded in carrying out the necessary reactions in the lab. Now they are looking step-by-step at how to apply the technology on a larger scale. Vermaas: "We are seeing—and rightly so—that the urgency of the climate crisis means there is more attention from both governmental bodies and the business community for the development and scaling up of carbon capture methods. This is a good thing, because ultimately it is essential that we bring the capture and conversion of CO₂ closer."

More information: R. Sharifian et al. Electrochemical carbon dioxide capture to close the carbon cycle, *Energy & Environmental Science* (2020). [DOI: 10.1039/D0EE03382K](https://doi.org/10.1039/D0EE03382K)

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