

# APPLICATION NOTE A2.4: Marine Carbon Dioxide Removal

## INTRODUCTION

Climate change has quickly become one of the most pressing issues of the 21st century, and there has been a large movement to reduce carbon emissions. However it has become evident that emissions reductions alone will not be enough to remain below the 2°C threshold.

As such, there has been growing interest in private industry to advance technologies to remove excess carbon from the atmosphere, specifically by using the ocean for long-term storage. These technologies are being classified as marine carbon dioxide removal (mCDR), and include methods such as Ocean Alkalinity Enhancement (OAE), Direct Ocean Capture, and coastal restoration.



Dissolved Gas Sensors

## GLOBAL CLIMATE CHANGE

Since the beginning of the Industrial Revolution, atmospheric CO<sub>2</sub> concentrations have been steadily increasing, driving climate change. This has led to several global issues including warmer average temperatures, an increase in the greenhouse effect, and ocean acidification.

The Paris Agreement, signed in 2015 by multiple nations, set a goal to keep the global increase in temperature below 2°C. To reach this goal not only will carbon emissions need to be reduced on a global scale, but carbon will need to be removed (either directly or indirectly) from the atmosphere at large-scale.

## Global GHG Emissions

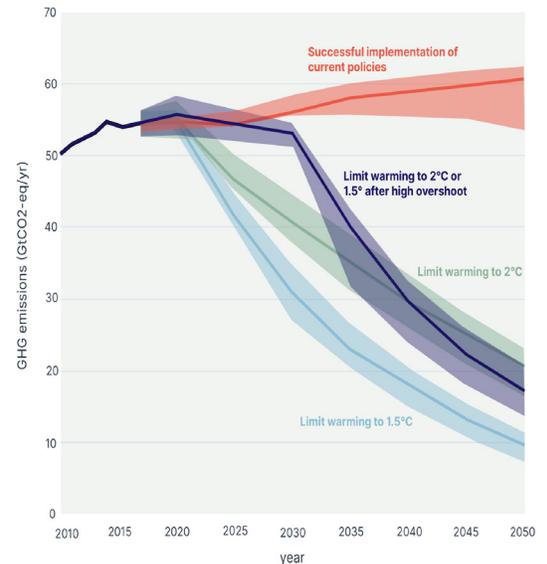


Figure 1. Projections of GHG emissions based on different IPCC scenarios. Image from: <https://www.planetarytech.com/science/climate-science-basics/>

## CARBON DIOXIDE REMOVAL METHODS

One of the most prominent mCDR technologies currently is OAE, with companies like Canada-based Planetary at the forefront. This technology is simple in theory and involves raising the alkalinity of a patch of water through the addition of a base (either mineral or liquid), causing the partial pressure of CO<sub>2</sub> in that patch to decrease. The change in partial pressure leads to either ingassing or a reduction in outgassing of CO<sub>2</sub>, with both scenarios leading to a net reduction in atmospheric CO<sub>2</sub>.

Another promising method is Direct Ocean Capture, which involves capturing CO<sub>2</sub> directly from seawater using electro dialysis to split the water molecules into acids and bases. The acid is then added back into the seawater stream to convert dissolved inorganic carbon (DIC) into CO<sub>2</sub> before moving through a degassing system to remove that CO<sub>2</sub>. The base created from the electro dialysis is reintroduced to the seawater stream post-CO<sub>2</sub> removal, and the seawater is returned to the ocean with the ability to absorb more CO<sub>2</sub> from the atmosphere. Companies like Captura are leading the way with this technology.

# Marine Carbon Dioxide Removal

## MEASUREMENT OF DISSOLVED CO<sub>2</sub> AND THE CARBONATE SYSTEM

Measurement of dissolved CO<sub>2</sub> is essential for ensuring that carbon concentrations are within regulatory limits. Each mCDR technique is unique, making continuous in situ dissolved CO<sub>2</sub> measurements a key element to any operation.

Dissolved CO<sub>2</sub> can be measured in a number of ways, including chemical laboratory analysis of water samples, using a liquid indicator dye that is monitored spectrophotometrically, and in situ measurement via diffusion across a membrane into an infrared gaseous CO<sub>2</sub> detector. Water sampling and laboratory analysis is labor intensive and generates a substantial time lag between the sampling time and the measurement results. Pro-Oceanus pCO<sub>2</sub> sensors utilize infrared detection and provide continuous long-term in situ measurements that allow for real-time monitoring changes in CO<sub>2</sub> as a result of mCDR.

## DISSOLVED CO<sub>2</sub> SENSORS

Pro-Oceanus offers several models of pCO<sub>2</sub> sensors for monitoring marine Carbon Dioxide Removal, including the [Mini CO<sub>2</sub>](#), [CO<sub>2</sub>-Pro FT](#), [CO<sub>2</sub>-Pro CV](#), and [CO<sub>2</sub>-Pro CV Atmosphere](#). Pro-Oceanus sensors utilize an advanced flat membrane technology that allow for the sensors to be continuously deployed for extended periods of time. This leads to less equipment downtime and less maintenance, resulting in better reliability and lower cost of ownership.

The sensors can be standalone with internal logging and battery power or they can be easily integrated into automated systems with feedback control with 4-20 mA, 0-5 V and RS-232 outputs. Flow-through and in-line adaptors are also available for simple integration into water monitoring systems. The right equipment choice is easy with consultation from [Pro-Oceanus' Scientific Team](#).



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CO<sub>2</sub>-Pro CV Atmosphere