



# The Challenge of Global CO<sub>2</sub> Reduction: The Potential of the Method Based on Seawater Electrolysis

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## Keywords

Carbon dioxide, Seawater, Electrolysis, Mineralization, Climate change

## Introduction

The atmospheric CO<sub>2</sub> concentration dramatically increased in the last 300 years, due to fossil fuels consumption and deforestation. From approximately 280 ppm before the start of the industrial revolution, about a 140 ppm upsurge was estimated. This phenomenon is understood to be responsible for a rise in global temperature, which will lead to glaciers melting and sea levels rising. Consequently, the research focused on atmospheric carbon capture and storage is fundamental for achieving the goals of the Paris Agreement concerning climate change mitigation.

A primary strategy to face these problems is to reduce the consumption of fossil fuels, by introducing, as an example, electric engines and renewable energies. Nevertheless, another essential task is the sequestration of the existing CO<sub>2</sub> excess in the atmosphere and its stable storage. From this point of view, for several years the most promising technique was the geological sequestration through injection and confinement of liquefied CO<sub>2</sub> into selected deep underground rock formations (such as saline reservoirs and depleted oil/gas fields). However, the hazard of potential CO<sub>2</sub> leakage is the main weak point related to this method. A more recent alternative was the geochemical sequestration, based on CO<sub>2</sub> injection into minerals that may drive carbonation reactions, producing stable carbonate rocks and implying a negligible risk of return to the atmosphere [1,2].

In our opinion, geochemical sequestration can be efficiently used and optimized by exploiting both seawater electrolysis and the oceans' natural CO<sub>2</sub> absorption feature.

## Oceans CO<sub>2</sub> Absorption

The oceans store about 60 times more CO<sub>2</sub> than the atmosphere, cover over 70% of the Earth's surface, and absorb approximately 25% of the anthropogenic CO<sub>2</sub> emissions.

The CO<sub>2</sub> assimilation is achieved both through biologically-

mediated and chemically-mediated sequestration: the former includes the processes that regulate the inorganic carbon incorporation into organic matter (photosynthesis by phytoplankton) and the transport to the deep sea (the portion of organic carbon not converted back to CO<sub>2</sub> via the food chain, sinks to seafloor sediments); the latter is based on the reaction of CO<sub>2</sub> with seawater to form carbonic acid, that breaks into hydrogen ions and bicarbonate (a chemical form of carbon that does not easily escape the ocean).

## Background to our proposal

Our research group previously proposed, in the past, a method for reducing CO<sub>2</sub> in the atmosphere based on the ocean's carbonate chemistry [3,4]. According to that scheme, when seawater is electrolyzed the dissolved CO<sub>2</sub> (incorporated in the carbonate family ions) reacts with the calcium-magnesium components producing insoluble carbonate minerals CaMg(CO<sub>3</sub>)<sub>2</sub>. If the process is carried out on the seawater surface layer the concentration of carbonate ions on the ocean's surface will decrease and the absorption of atmospheric CO<sub>2</sub> should be enhanced. Moreover, seawater electrolysis produces hydrogen, which can be stored and used/sold as an energy resource. The electrolysis system must be performed using carbon-free energy (such as solar, to do not release CO<sub>2</sub>). A similar approach was recently proposed by other researchers, confirming the validity and feasibility of the idea [5].

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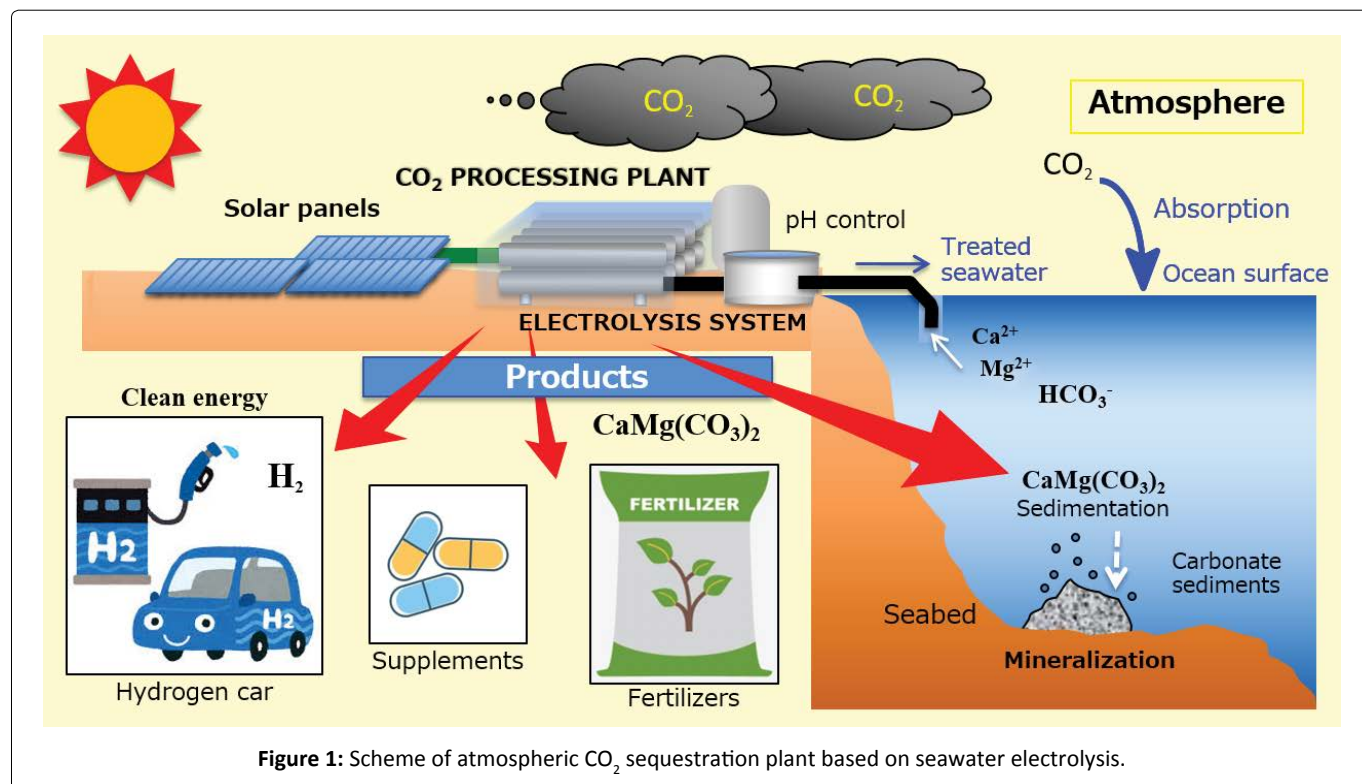


Figure 1: Scheme of atmospheric CO<sub>2</sub> sequestration plant based on seawater electrolysis.

However, it must be considered that if the produced carbonate minerals are left to sediment in the ocean's deep layer the seawater alkalinity will tend to decrease, the ability to absorb CO<sub>2</sub> will be reduced, and effects on the marine environment may occur. Therefore, we propose to revise the process as follows.

### Suggestions for an improved and efficient CO<sub>2</sub> sequestration plant based on seawater electrolysis

The main part of our CO<sub>2</sub> sequestration plant will be the electrolysis system, which could be built on the coast or as an offshore platform. The energy will be provided by a dedicated solar power system (Figure 1).

The insoluble carbonate minerals will be retrieved and reused for many purposes (such as the production of fertilizers or drugs/supplements, use in the construction industry, etc.) instead of letting them deposit on the seabed.

Due to the effect of increased CO<sub>2</sub> concentration in the atmosphere and the abovementioned natural CO<sub>2</sub> absorption by the ocean, the seawater pH showed a decrease of about 0.05 in the last 30 years. As a consequence, it is expected that the CO<sub>2</sub> absorption rate will tend to decrease. Therefore, it will be important not only to pretreat/purify the input seawater (before the treatment), to produce water pure enough for electrolysis, but also to control the characteristics of the output seawater (after the treatment) and to check/restore the pH and the chemical components (Ca and Mg) depleted during the process.

The main reactions of the electrolysis process will be: on the cathode of the electrolytic cell will take place the reactions

producing hydrogen ( $\text{H}_2\text{O} + \text{e}^- \rightarrow \frac{1}{2}\text{H}_2 + \text{OH}^-$ ) and carbonate minerals ( $\text{Ca}^{2+} + \text{Mg}^{2+} + 2\text{HCO}_3^- + 2\text{OH}^- \rightarrow \text{Ca-Mg}(\text{CO}_3)_2 + 2\text{H}_2\text{O}$ ); on the anode, through the water-splitting reaction ( $\text{H}_2\text{O} \rightarrow 2\text{H}^+ + \frac{1}{2}\text{O}_2 + 2\text{e}^-$ ), chloride ion oxidation reaction will be achieved ( $2\text{Cl}^- \rightarrow \text{Cl}_2 \rightarrow \text{Hydrolysis} \rightarrow \text{ClO}^-$ ).

The ClO<sup>-</sup> ion may affect the marine ecosystem due to its potential effect on the biota (it has biocide property), and it is produced proportionally to the electrolysis rate. It can be eliminated using activated carbon or electrolytic reduction treatment.

As a result of small-scale experiments, no CO<sub>2</sub> release occurs during the production of carbonate mineral precipitates. In addition, we verified that by mixing the cathode-treated seawater and the anode-treated seawater, water having a slightly alkaline pH compared to the input seawater is obtained. Therefore, it is also possible to contrast the acidification of seawater and to promote the absorption of atmospheric CO<sub>2</sub>.

To sum up, the main features of the proposed method are:

- 1) Seawater electrolysis can effectively sequester atmospheric CO<sub>2</sub>.
- 2) CO<sub>2</sub> is converted into solid stable carbonate minerals.
- 3) Useful resources (minerals and hydrogen gas) can be generated and reused.
- 4) By using carbon-free electricity (solar or wind energy) new CO<sub>2</sub> is not released.
- 5) It can evolve as a new type of business.

This proposal requires the examination and contribution

from experts in many branches of environmental sciences. We will be glad to receive comments and opinions.

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