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Net carbon dioxide removal via electrolytic seawater mineralization

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The trapping of carbon dioxide (CO_2) as an aqueous (bi)carbonate ion (e.g., HCO_3^-, CO_3^{2-}) or as a mineral solid is attractive because of favorable thermodynamics, and the safety and permanence of storage. We have proposed an approach to rapidly precipitate Ca- and Mg- carbonates and hydroxides from seawater to achieve CO_2 removal. This *Equatic*^{TM} process electrolytically forces mineral carbonate precipitation thereby consuming prevalent CO_2 that is dissolved in seawater by locking it within carbonate minerals, and simultaneously producing alkaline mineral hydroxides that when dissolved in seawater enable the drawdown of atmospheric CO_2 into the seawater, representing net CO_2 removal. Specifically, the net reaction for $CaCO_3$ (aragonite) precipitation is $Ca^{2+} + CO_2 + 2OH^- \rightarrow CaCO_3 + H_2O$. The precipitation of magnesium carbonate is kinetically limited, thus, alkalinity forces the precipitation of Mg^{2+} as $Mg(OH)_2$ (brucite): $Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2$.Therefore, 1 mol of CO_2 is captured by 2 mol of OH^- through the production of 1 mol $CaCO_3$. On the other hand, only 1.2 mol of OH^- are required per 1 mol CO_2 stored as dissolved HCO_3^- and CO_3^{2-} ions. This is because when dissolved into seawater, every mol of $Mg(OH)_2$ leads to the absorption of up to ~1.7 mol of CO_2(actual ratio depends on pH). The formation of magnesium carbonates, e.g., nesquehonite ($MgCO_3{\cdot}3H_2O$) and hydromagnesite ($Mg_5(CO_3)_4(OH)_2{\cdot}4H_2O$) can also be achieved by equilibrating alkalinized seawater with air (i.e., ~400 ppm CO_2), yielding two limiting cases: (*Case 1*) $CaCO_3$ + $Mg(OH)_2$ (i.e., 11% solid + 89% aqueous CO_2), and (*Case 2*) $CaCO_3$ + $MgCO_3$ production (i.e., 100% solid CO_2 sequestration). Here, we describe the CO_2 mass balances of the process. This analysis offers a quantitative basis for assessing the CO_2 removal potential of the technological approach and developing a robust measurement, reporting, and verification (MRV) strategy. In addition, we describe the pilot project at AltaSea at the Port of Los Angeles in California which will demonstrate an energy intensity of 2.5 MWh per t CO_2 removed, identify the necessary data for carbon accounting and potential design inefficiencies or improvements, and inform design of full-scale operations.