Ocean Alkalinity Enhancement: At a Glance

Ocean alkalinity enhancement (OAE), also termed enhanced weathering (EW), aims to alter seawater chemistry, usually by spreading finely ground alkaline minerals like silicates and carbonates in seawater or on coastal lands. (OAE can also be driven by electrochemistry; see related fact sheet). The pulverized minerals dissolve slowly, on the order of years and decades, adding alkalinity to the ocean so that it can absorb additional CO_2 from the atmosphere. This approach dramatically accelerates natural mineral weathering processes, which normally can take thousands of years. This can also decrease ocean acidification.[50] Source materials for OAE—such as lime—would be mined on land or obtained from industrial processes, ground, and then spread on beaches or added to seawater via pipelines or ships.[51] Particles would have to be very small, and locations for mineral addition carefully selected.[52]

Potential Scale of Carbon Storage: Modeling suggests that 75 years of OAE deployed at global scale, affecting most of the surface ocean, would enhance ocean carbon dioxide absorption by 156 gigatonnes of carbon (GtC), an approximate average rate of around 2 gigatonnes of carbon per year (GtC yr^{-1}).[53] This annual uptake is equivalent to about 6 percent of global atmospheric CO_2 emissions from fossil fuel burning in 2018.[54]

Cost: The estimated present cost for OAE with carbonates is about $70 to $120 per tonne of CO_2. At that cost, removing 2 GtC per year via OAE at the scale described above would cost roughly $500 billion to $800 billion per year, or five to eight times all international climate finance funding pledged by parties to the United Nations Framework Convention on Climate Change in 2009.[55] There are currently no detailed cost estimates for global-scale deployment of silicate mineral–based OAE methods.

Duration of Carbon Storage: The length of time that CO_2 could be removed from the atmosphere as a result of OAE is uncertain. It depends on water column physics, chemistry, and biology, but in some cases storage from OAE could last more than a century.[56]

Technical Readiness: The chemistry behind OAE is well established, but the technique poses logistical challenges. Mining, grinding, and transporting enough alkaline material from land to distribute in the marine environment would require massive infrastructure and long supply chains. The energy requirements and CO_2 emissions of OAE operating at full scale are likely to be high, but they are not well researched.[57]

Potential Risks and Benefits (Social and Environmental): Hazards of terrestrial mining are well known; they include harm to local biodiversity and quality of air and water, as well as common social challenges such as safety risks to miners and exposure to pollutants in surrounding communities. Once deployed in the ocean, OAE could increase levels of toxic metals and other minerals or alter the mix of phytoplankton species present, with unknown net effects on biodiversity.[58] However, OAE is expected to help decrease ocean acidification and thereby potentially aid some open-ocean marine life, such as plankton with hard shells.[59] Impacts of coastal alkalinity enhancement (i.e., enhanced weathering) on seashore and nearshore wildlife and vegetation are presently unknown.

Outstanding Questions: It's still unclear whether enough minerals could be prepared for OAE or EW without the serious environmental and social harms associated with most mining activities.[60] The added crushed mineral material itself may carry impurities, such as metallic elements or other minerals that could themselves have environmental impacts. In addition, national and international policies and agreements are not definitive on OAE; most do not comment on it explicitly but do regulate addition of different types of materials and known pollutants to the ocean.[61] As for all marine CDR techniques, verification of these methods would require analysis of total CO_2 emissions associated with building and operating OAE infrastructure and transporting the terrestrially mined materials to appropriate places in the ocean.

50 National Academies of Sciences, Engineering, and Medicine (hereinafter NASEM), *A Research Strategy for Ocean-Based Carbon Dioxide Removal and Sequestration* (Washington, D.C.: National Academies Press, 2022), https://doi.org/10.17226/26278.

51 Ibid.

52 Ibid; Daniel J. Burt, Friederike Fröb, and Tatiana Ilyina, "The Sensitivity of the Marine Carbonate System to Regional Ocean Alkalinity Enhancement," *Frontiers in Climate* 3 (July 2021), https://www.frontiersin.org/article/10.3389/fclim.2021.624075.

53 Ibid.

54 International Energy Agency, "Global Energy & CO_2 Status Report 2019," 2019, https://www.iea.org/reports/global-energy-co2-status-report-2019.

55 Ibid; Organisation for Economic Co-operation and Development, *Climate Finance and the USD 100 Billion Goal*: *Climate Finance Provided and Mobilised by Developed Countries in 2016–2020* (Paris: OECD Publishing, 2022), https://doi.org/10.1787/286dae5d-en.

56 NASEM, *A Research Strategy*.

57 Ibid.

58 Lennart T. Bach et al., "CO_2 Removal With Enhanced Weathering and Ocean Alkalinity Enhancement: Potential Risks and Co-benefits for Marine Pelagic Ecosystems" *Frontiers in Climate* 1 (October 2019), https://www.frontiersin.org/article/10.3389/fclim.2019.00007; Aaron Ferderer et al., "Assessing the Influence of Ocean Alkalinity Enhancement on a Coastal Phytoplankton Community," *Biogeosciences Discussions* [preprint] (2022), https://doi.org/10.5194/bg-2022-17.

59 Bach et al., "CO_2 Removal With Enhanced Weathering."

60 See, for example, Phil Renforth, "The Potential of Enhanced Weathering in the UK," *International Journal of Greenhouse Gas Control* 10 (September 2012): 229–43, https://doi.org/10.1016/j.ijggc.2012.06.011.

61 NASEM, *A Research Strategy*.