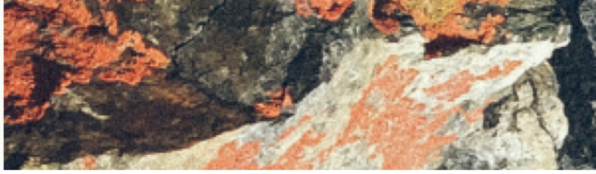
Frontier



A primer on Ocean Alkalinity Enhancement (OAE)

Restoring ocean health requires global solutions

Climate change destabilizes ocean ecosystems. While *local* efforts, such as creating marine protected areas and restoring coastal habitats, can address issues like overfishing and pollution, they are not enough to tackle the *global* drivers of rising sea levels, warmer waters, and increased acidity. **Those challenges are directly linked to the concentration of CO_2 in the atmosphere. To safeguard ocean health, we need solutions that radically reduce emissions *and* remove huge amounts of CO_2.**

Adding controlled amounts of alkalinity to ocean ecosystems is one of those solutions

Ocean Alkalinity Enhancement (OAE) involves adding alkaline substances—like crushed limestone or magnesium hydroxide—to seawater. This process makes seawater slightly more basic, helping it absorb more CO_2 from the air and locking it away as stable forms of carbon that can stay in the ocean for centuries and longer.

OAE has the potential to address climate change *and* improve ocean health

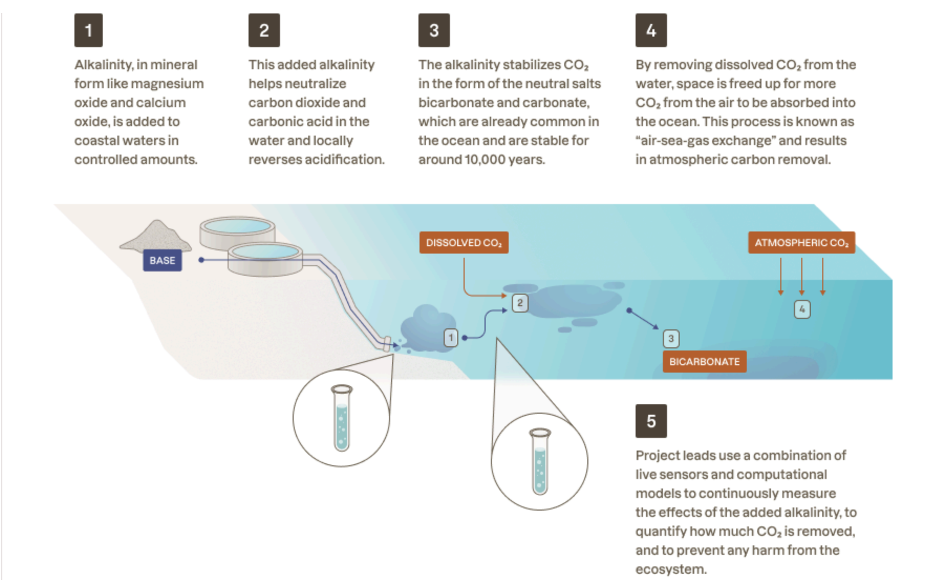
OAE is particularly promising because it tackles two problems at once:

- It locally reduces acidification, creating better conditions for shellfish, corals, and other marine life.
- It removes CO_2 from the atmosphere, with potential for gigaton-scale impact.

OAE also has some practical advantages: it doesn't require vast land areas or underground storage. Instead, it can piggyback on existing coastal infrastructure, considerably reducing capital expenditure. OAE has the potential to improve waste water treatment processes and create up to 17,500 local jobs. And because it works by enhancing the ocean's natural carbon cycle, it's durable and globally scalable.

OAE is effective and safe for marine ecosystems — if done responsibly

So far, lab and field trials show that OAE works: when alkalinity addition is carefully controlled, it helps seawater absorb more CO_2 and reduces local acidity—without harming marine life. The ocean's buffering system resists large shifts in pH, offering a natural safety mechanism. To avoid unintended consequences, OAE projects should also include strict safety checks—like testing materials before use, monitoring ocean chemistry and biology closely, and being ready to stop dosing if thresholds are crossed.



Infographic displaying how ocean alkalinity projects work

FAQs

Isn't the ocean already a carbon sink?
Yes, the ocean already absorbs about 25% of the CO_2 we emit — but it's doing so at a cost. More CO_2 makes it more acidic, which harms marine life and reduces its ability to absorb additional CO_2[1]. OAE can safely increase the ocean's storage potential *and* counteract local acidification.

What are the different technological approaches to OAE?
Approaches include the addition of alkaline minerals directly into seawater (e.g. Planetary), or into inland water streams like rivers (e.g. CarbonRun), wastewater treatment systems (e.g. CREW), or adding alkaline solutions produced through electrochemical processes (e.g. Ebb Carbon).

What exactly gets added to the ocean?
Common materials include hydroxide-based minerals and solutions like magnesium hydroxide, sodium hydroxide, or calcium hydroxide (used in antacids). Importantly, these materials consist of elements that are already abundant in ocean water: Calcium (Ca), Magnesium (Mg), Hydroxide (OH), etc. Any material that is being added is subject to rigorous feedstock testing to monitor impurities.

One specific approach, known as **ocean liming**, uses hydrated lime (calcium hydroxide) to rapidly raise alkalinity. Lime dissolves quickly and efficiently, offering faster CO_2 uptake than crushed rock.

Where has OAE been done?
Ocean Alkalinity Enhancement has been tested or testing is underway in more than a dozen controlled field trials across diverse marine environments, from Halifax Harbour, Canada to Heron Island, Australia. These trials are led by non-profits (WHOI, Carbon to Sea), academic universities (Dalhousie University), and companies (Planetary Technologies, Ebb Carbon) and aim to further our understanding of OAE in real-world environments at increasing scales. See Ocean Visions' OAE field trial database for a full list of trials. These field trials include fundamental studies[2], tank experiments[3], and mesocosm[4] as well as batch field trials that have demonstrated the effectiveness and environmental safety of OAE at smaller scales. There are also many examples of alkalinity being added to reverse the damage of acidic waters on riverine and coastal organisms, such as shellfish, salmon, and coral.

What do responsible OAE projects look like?
Responsible OAE projects involve partnering with scientists, Indigenous groups, and local communities on project design from the start. They carry out controlled, stage-gated pilots in coastal zones which allow scientists to measure impacts on local ecosystems and carbon cycles. They rigorously and continuously monitor water chemistry, biological health, and carbon accounting, while transparently sharing their findings.

How is carbon actually measured and verified?
Scientists calculate how much CO_2 was removed and stored by measuring the alkalinity potential and rate of dissolution at the point of dosing. To do that, they use aquatic sensors and tracer techniques that track (1) the alkalinity dispersion, (2) changes in pH, (3) total alkalinity, (4) dissolved inorganic carbon and (5) rate of air sea gas equilibration. Some companies pre-dissolve the alkalinity before adding it to the ocean, which simplifies assessing the rate of dissolution. As an example, Planetary delivered the first independently verified carbon removal credits in 2025 using Isometric's measurement protocol for OAE in coastal outfalls.

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[1] National Oceanic and Atmospheric Administration on impacts of ocean acidification
[2] Establish basic knowledge of how marine systems work and inform further research.
[3] Apply insights from fundamental studies to test specific scenarios in controlled environments.
[4] Extend the findings from tank experiments to larger, semi-natural environments.

How big could OAE get?

The US National Oceanic and Atmospheric Administration estimates it has the potential to remove 1-15+ billion tons of CO_2 annually at a cost of $50-160/ton at scale[5]. The range reflects uncertainty around how to source and distribute alkalinity economically at scale.

Who is Frontier, and why are they involved in OAE?

Frontier is an advance market commitment to buy high-quality carbon removal. We believe that to avoid the worst impacts of climate change—including those already hitting our oceans—we must both rapidly reduce emissions and permanently remove CO_2 already in the atmosphere. We work with over 60 independent experts to define what "high-quality" removal looks like: it must be permanent, safe, additional, and measurable. Then we support early-stage companies and researchers working on solutions that meet that bar, which includes Ocean Alkalinity Enhancement. Learn more about our evaluation criteria here and how early buyers can support responsible OAE here.

Where can I learn more?

- Isometric – Protocol for Ocean Alkalinity Enhancement from Coastal Outfalls
- Carbon to Sea – Why is it important to research ocean alkalinity enhancement?
- Carbon to Sea - Field summary from 2025's Annual Convening
- Planetary - Library of resources on the efficacy and safety of OAE
- Ocean Visions - OAE Overview, OAE Roadmap & Field Trial Map
- National Academies of Sciences (NASEM) – Ocean-based Carbon Dioxide Removal Report (2022)
- Carbon to Sea – Public-Facing Briefs and Research Updates
- Copernicus - Guide to Best Practices in Ocean Alkalinity Enhancement Research
- C&EN - Oceans as climate change allies: can climate catastrophe be stymied by tweaking the seawater chemistry?

[5] National Oceanic and Atmospheric Administration's Strategy for Carbon Dioxide Removal Research