11.14.24 Ebb Carbon/ Ocean Visions Launchpad Summary

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The team at Ebb Carbon has been grateful to have the support at Ocean Visions Launchpad in our pursuit of safe and scalable marine carbon dioxide removal (mCDR). Ebb Carbon was a member of the first cohort of the Launchpad program as a competitor for the ocean-based CDR XPRIZE. Ebb Carbon's technology uses electrochemistry to separate seawater or brine into acid (hydrochloric acid) and base (sodium hydroxide) streams. The acid is removed from the system, and the base and seawater streams are recombined and returned to the surface ocean. This process enhances the ocean's ability to draw down atmospheric CO_2 and to store it safely as bicarbonate. As an electrochemical pathway for ocean alkalinity enhancement (OAE), this method increases seawater alkalinity by removing acidity from seawater, rather than adding an alkaline source material to seawater. Because the movement of atmospheric CO_2 into the ocean takes place over significant timescales (weeks to years), careful consideration of measurement and modeling techniques are required to verify carbon storage, due to the dilution of alkalinity into coastal oceans with significant natural background variation in carbonate chemistry. Scaling this technology requires robust measurement, reporting, and verification (MRV) and environmental safety methodologies.

Our first Launchpad meetings brought together two of Ebb Carbon's four co-founders, Ben Tarbell (CEO) and Matthew Eisaman (Chief Scientist and Associate Professor at Yale University at the Yale Center for Natural Carbon Capture) with Ocean Visions' Nikhil Neelakantan and Launchpad advisors Heather Kim (Woods Hole Oceanographic Institution) and Todd Martz (Scripps Institution of Oceanography, UC San Diego). Initial conversations laid out requirements and questions for Ebb Carbon's success, including the following:

- Measurement to verify CO2 drawdown and sequestration:
  - What is the range of detectability of the OAE signal given current sensors and ocean models?
  - What improvements to these technologies and to Ebb Carbon's deployment design will enable robust MRV?
- Environmental safety:
  - How does OAE impact marine ecosystems? How do we evaluate potential benefits of deacidification in the marine environment?
  - Can electrochemical mCDR technologies using desalination brine reduce the environmental impacts of existing and future desalination outfalls?
- Optimizing site selection and design:
  - How do OAE developers weigh out design considerations when seeking appropriate deployment locations, including local and regional oceanography, existing infrastructure, acid offtake options, and economic considerations?
- Policy and social license:
  - mCDR processes fall in slow and non-standard permitting regimes. What progress needs to be made to streamline this process?
  - How do we best reach the groups and communities that must support and/or be involved in a project in order for site development to move forward?
  - What educational materials must be developed around the need for CDR, the appropriate verification of mCDR, and potential environmental impacts of both mCDR and nonaction?

Launchpad advisors provided significant guidance on each of these topics, with particular focus on their subject matter expertise in marine biogeochemistry, with a modeling perspective from Heather Kim and instrumentation and observational networks from Todd Martz. These meetings were critical for Ebb Carbon to understand limitations and opportunities in current ocean modeling and sensing, at an early stage in mCDR research before there was much community consensus on the extent and detectability of OAE, and before the first protocols for OAE MRV were available.

The advisors were influential in their review of scientific proposals: a 2022 grant from the National Oceanographic Partnership Program enabled a partnership between Ebb Carbon, Pacific Northwest National Laboratory, University of Washington, and NOAA PMEL on Electrochemical Acid Sequestration to Ease Ocean Acidification (EASE-OA). This project involves an ongoing a pilot test of Ebb Carbon's 100 ton CO_2/yr electrochemical system, with mesocosm experiments to evaluate carbon storage through varied seawater carbonate sensing and sampling methods. Investigation of biological impacts involved exposure of local marine species, chosen for their importance as salmon feedstocks, to alkalinity enhancement (Jones, K., Hemery, L., Ward, N., Regier, P., Ringham, M., and Eisaman, M.: Biological response of eelgrass epifauna, Taylor's sea hare (*Phyllaplysia taylori*) and eelgrass isopod (*Idotea resecata*), to elevated ocean alkalinity*. EGUsphere [preprint],* https://doi.org/10.5194/egusphere-2024-972, 2024). This project also involved simulation of potential and scaled alkalinity releases from the Ebb Carbon system into Sequim Bay, WA, in the Salish Sea Model, demonstrating the potential for bay-scale acidification mitigation as a co-benefit of mCDR (Khangaonkar, T., Carter, B.R., Premathilake, L., Yun, S.K., Ni, W., Stoll, M.M., Ward, N.D., Hemery, L.G., Sanchez, C.T., Subban, C.V. and Ringham, M.C., 2024. Mixing and dilution controls on marine CO2 removal using alkalinity enhancement. *Environmental Research Letters*, *19*(10), p.104039.) This grant has enabled Ebb Carbon to further our research and operation in Washington, which as of November 2024, has extended to initial controlled releases of alkalinity-treated seawater from PNNL facilities into Sequim Bay, and to the successful permitting of an Ebb Carbon commercial pilot in nearby Port Angeles, WA, to be commissioned in 2025. Review of this proposal by Launchpad advisors focused both mesocosm and modeling components, and provided useful perspectives for essential components of future scientific proposals.

Ebb Carbon's participation in Launchpad meetings shifted to Mallory Ringham, an observational chemical oceanographer leading MRV, in late 2022, and conversations naturally shifted from defining requirements for ideal OAE sites and deployment strategies to more targeted field trials. As Ebb Carbon moved towards collecting baseline carbonate chemistry and oceanographic data at potential field sites, the selection and purchase of appropriate ocean sensors became more pressing. Discussion over the benefits and challenges of specific technologies, relative importance of specific parameters, requirements for personnel and in-water support, and the eventual connection between measurements and models streamlined Ebb Carbon's evaluation of options in this space.

Our discussions in this program were significant for the early development of Ebb Carbon's MRV strategy and thinking on site selection. As mCDR has gained attention and frequent community workshops and conferences have fostered connections across the field, we have been able to focus our efforts on the hard work of operating a pilot and developing new systems. We applied Heather and Todd's advice to our measurement and modeling expectations, and paused Launchpad meetings. Currently, Ebb is a Top 20 finalist in the XPrize competition to demonstrate scalable CDR technologies, and a Phase 1 Semifinalist in the US Office of Fossil Energy and Carbon Management CDR Purchase Pilot Prize through the Department of Energy. As we pursue these prizes and learn from current and future deployments, we are excited to share our work and the development process that has worked for us—including the value of expert advice provided through Ocean Visions.