Carbon to Sea Initiative

Proceedings of the 2025 Carbon to Sea Annual Convening

Gathering to determine whether OAE has a future as a climate solution

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Foreword

DR. ANTONIUS GAGERN
CARBON TO SEA

In May 2025, we hosted our third Carbon to Sea Annual Convening — a milestone gathering that brought together nearly 200 leaders from academia, industry, government, and civil society. Over three days of deep conversation, shared meals, and rooftop reflections, one sentiment kept surfacing: amazement at how far this field has come in such a short time.

When we launched Carbon to Sea in 2023, ocean alkalinity enhancement (OAE) was largely an idea, known to only a handful of experts and often met with skepticism or concern. Today, the conversation has advanced in fundamental ways.

We now see a growing portfolio of potential OAE pathways — more than a dozen, each exploring different mechanisms, materials, and models. Although there are still important questions to answer, there has been a significant increase in the volume of evidence that can help determine which OAE pathways could be pursued safely, effectively, and responsibly.

> “Despite the differences in perspective and background that people bring to this work, what has emerged is a culture of constructive, rigorous discourse.”

That kind of progress depends on the willingness of people across sectors — scientists, entrepreneurs, public servants, and advocates — to step outside their institutional lanes. That’s not a small ask. Academia moves deliberately. Startups race to survive. Non-governmental organizations (NGOs) are grounded in their mandates and in maintaining public trust. Government agencies follow procedure and precedent. Each has its own clock, its own language, and its own constraints. But despite the differences in perspective and background that people bring to this work, what has emerged is a culture of constructive, rigorous discourse.

This Proceedings document summarizes three days of presentations, panel discussions, and workshops. I want to highlight what stood out to me this year:

- **There is growing scientific evidence that environmental risks can likely be managed for multiple OAE approaches.** Yet this assessment is hard to discern given that many studies report on conditions that do not reflect real-world scenarios. Instead, they test outlier scenarios, where alkalinity is higher than would be optimal for carbon removal. This raises an important question for sustaining critical independent academic research: how can OAE research on realistic

deployment conditions, and potentially "boring" results, still pique academic curiosity and contribute to early career advancements? What if the most relevant findings are not the most publishable? This is an important challenge the field must address.

- **We now have line of sight for MRV in OAE.** For the first time, we have real-world implementation of MRV for OAE in a market-facing context — a critical milestone enabled by collaborative efforts between project developers, researchers, and verifiers. These early projects are reason for optimism that near-field measurements, combined with well-validated models, can reduce uncertainty to quantifiable and traceable bounds. Still, these early approaches are imperfect and key methodological questions remain. The only way to improve credibility and build confidence in MRV across the field is through a significant increase in controlled real-world trials which, combined with standardized and transparent data sharing, can generate a robust and trusted evidence base.

- **A new framework for technoeconomic and life cycle analysis brings much-needed consistency, transparency, and comparability to the field.** Published by researchers at the Heriot-Watt University, the framework standardizes key assumptions — from CO_2 chemistry to uncertainty and time lags — enabling true apples-to-apples comparisons across approaches. Crucially, it also looks forward, incorporating methods to project how performance and costs could improve with scale, rather than focusing only on today's numbers.

- **If OAE is going to have access to robust compliance markets in the coming years, scientific rigor and transparency will be essential.** Enabling responsible OAE will require alignment between scientific standards and private sector needs, but that won't happen by accident. That's why cross-sector collaboration is essential to navigate tensions between urgency, rigor, and affordability.

I'm deeply grateful to all who contributed to this Convening — and to the broader momentum behind it. The work ahead is complex, but we are not doing it alone. And that, more than anything, gives me confidence in where we're headed.

I also want to give special thanks to Lydia Kapsenberg at CEA Consulting, for her help in putting this document together, and to the entire team that made this year's Convening possible.

DR. ANTONIUS GAGERN
EXECUTIVE DIRECTOR
THE CARBON TO SEA INITIATIVE

Carbon to Sea Initiative

State of the Field

Opening Session

Scientific Progress + Research Updates

DR. DAVID KELLER
CARBON TO SEA

Charting the rapid increase of OAE research

To open the session on Scientific Progress and Research Updates, Keller presented a look back on OAE and how the field evolved to where it is today, from early research starting over 35 years ago to the rapid expansion of research in the past five years. He described three phases.

The first phase consisted of what would become foundational research in mineralogy, chemical oceanography, and climate science. This work set the stage for the first OAE publication, "Sequestering atmospheric carbon dioxide by increasing ocean alkalinity," by Haroon Kheshgi in 1995.

Over the next 25 years, progress was slow, funding was limited, but the OAE hypothesis was tested by a small number of individuals. Advancements were made on chemical equations, technology concepts, small-scale lab experiments, idealized OAE simulations with models, and indirect OAE research, including ocean acidification mitigation in shellfish hatcheries and one notable field experiment in a coral reef. By 2019, 99 papers on OAE were published, largely by U.S. and European Union (EU) research institutions.

The third phase is where OAE research began to flourish. Following the publication of influential reports – including the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C in 2018, which stated definitively that carbon dioxide removal (CDR) is necessary, and the U.S. National Academy of Sciences, Engineering and Medicine (NASEM) 2022 report "A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration" – funder interest and momentum on OAE research increased. Major national and international programs arose in the EU, China, Germany, and the U.S., including the launch of Carbon to Sea in 2022.

Since 2019, OAE publications have tripled. Research to date has concentrated on OAE efficiency, environmental impacts (largely on impacts to phytoplankton), technology, and costs, with social science and communications becoming more recent topics of interest. Keller closed by saying,

> "We have a clear understanding of what, how, and where research has been conducted... And there's a lot in the pipeline."

DR. LENNART BACH
UNIVERSITY OF TASMANIA

The case for researching OAE under plausible conditions instead of "No Man's Land" studies

Bach presented a synthesis of OAE modeling and biological impact research, concluding there is currently little evidence for adverse biological impacts due to changes in carbonate chemistry expected for realistic OAE deployments. He explained that many studies simulate alkalinity enhancements that are much more pronounced than what is realistically plausible and when biological impacts are observed, they occur under conditions that go far beyond what could be expected with OAE.

Bach presented model scenarios with OAE deployed globally along coastlines for CO_2 removal of 200 gigatonnes (Gt) over 20 years. Even under this highly optimistic scenario, 75% of the global surface ocean would experience a change in total alkalinity of 0 to 100 µmol kg^{-1}, with only enclosed basins experiencing greater than 200 µmol kg^{-1} increase in total alkalinity. Biological studies, in contrast, have mostly assessed much higher alkalinity perturbations, from +200 to greater than +3000 µmol kg^{-1} total alkalinity, and it's mainly at those higher exposures where most biological responses have been documented (i.e., positive, negative, or unqualifiable changes).

In addition, Bach pointed out a mismatch in exposure durations, where experiments often use exposure times that are longer than what might be expected in the field over meaningful spatial scales. While experiments with high total alkalinity treatments and long exposures can be invaluable for revealing mechanistic responses to OAE, Bach argued that they should not be called "OAE studies" because it is an unrealistic representation of OAE. This highlights the need for applied experiments and aligned communication within the field, since extreme perturbations assess a stressor relevant for OAE, but not the stress level that is representative for it.

Bach contextualized the biological tolerance of moderate alkalinity perturbations observed in lab and mesocosm studies (e.g., +200 µmol kg^{-1}) with natural variability of total alkalinity. The global alkalinity gradient in the open ocean and across natural analogs, such as the estuaries and marginal seas, naturally support diverse and productive marine life despite a variation in total alkalinity that would be of similar or greater magnitude than what would need to be achieved with OAE. Excluding OAE's impacts on sediment dynamics (for which little is known), Bach indicated optimism and encouraged the audience to,

> "Acknowledge that alkalinity changes realistically imposed through OAE would generally not act as a strong stressor."

Bach called for expanding the focus of environmental impact studies from carbonate chemistry alone to investigating potential risks from specific feedstock components (e.g., trace metals, particles, and nutrients). He also emphasized the importance of independent, yet better-aligned, collaboration with practitioners to ensure that academic OAE research does not disconnect from real-world OAE developments.

DR. DARIIA ATAMANCHUK
DALHOUSIE UNIVERSITY

Quantifying CDR in the Real World

Based on the past and ongoing OAE pilot studies in Halifax Harbor, Canada, Atamanchuk provided an overview of the realities of measuring OAE in the field. Her work demonstrates that in-water measurements and technologies are capable of delivering data on spatiotemporal scales that can inform quantification of CDR. These findings could help inform the development of MRV for OAE in the near-term and at scale.

Atamanchuk began her presentation describing possibilities to measure OAE indicators despite the challenges of measuring CDR directly in the field. When alkalinity is increased, signatures of the perturbed carbonate system — pH, pCO_2, dissolved inorganic carbon (DIC), total alkalinity — change over time, but not all in the same way. Total alkalinity decays with dilution, while pH and pCO_2 also decay with dilution but faster due to CO_2 intrusion over time. Consequently, a DIC signal over time, which would constitute the most direct signal of CDR, is difficult to detect and will likely not be possible at current scales.

Atamanchuk showed datasets of total alkalinity and pCO_2 signals from her studies in Halifax that were able to demonstrate changes in line with expectations of an OAE intervention. The OAE signal of total alkalinity was measurable throughout the harbour, while the pCO_2 OAE signal was clearly detected only in the near field. The scale of background variability and the resolution of data were shown to play a critical role in detecting and monitoring OAE signals in the field. These data showed that while direct measurements of CDR will likely be very challenging, estimating CDR using observations and numerical models is viable. The findings by Atamanchuk demonstrate that observations play an important role in providing measures of the initial shifts in the carbonate system due to the OAE activity and can thereby serve as proxy measurements of the CDR potential in the future. Observations also provide the critical data to refine, validate, and parameterize the numerical models and determine the baseline and OAE perturbation. Numerical models are needed for estimating CDR and the counter factual.

With high resolution observations and models, the pilot studies in Halifax can be considered a “gold-standard” approach to CDR quantification. Atamanchuk’s lessons learned centered on the importance of focusing on what is both important and measurable, saying,

> “Not everything is measurable and not everything needs to be measured.”

She highlighted the need for cost-effective, scalable observing systems that can inform and validate numerical models at relevant scales. Overall, Atamanchuk provided optimistic insights to the feasibility of quantification and emphasized the need to further validate and extrapolate these findings to other large-scale OAE field experiments.

DR. ADAM SUBHAS
WOODS HOLE OCEANOGRAPHIC INSTITUTE

How community engagement shaped plans for the first major OAE field trial in the U.S.

Subhas, the Principal Investigator on what will become the first academic ocean-based carbon dioxide removal (oCDR) field trial in U.S. waters, provided insights into the work he did to gain government and community approval for field research. His small-scale research project was approved after exhaustive review by the U.S. Environmental Protection Agency over the course of two administrations.

Subhas is planning to measure the effects of a one-time, controlled release of liquid sodium hydroxide (NaOH) miles off the coast of Maine this summer. The field trial is expected to answer key questions about effectiveness, by improving the connection between measurements and models, and potential environmental impacts of OAE. As part of the field trial preparation, Subhas and his team conducted a tracer experiment and demonstrated the ability to disperse and track alkalinity in the ocean at high precision. Subhas developed a boat discharge system to rapidly mix NaOH into the ocean with real-time data readouts, and tested this system at near-full scale in a 10-million liter open-air tank this Spring. During the field trial, the OAE signal will be observed in units of pH and pCO_2 (and not DIC) and is expected to reach a pH of ~8.39, whereas natural background ranges from pH 8.0 to 8.1.

Subhas emphasized the team's extensive public engagement and education efforts around oCDR and OAE, including many meetings with fishermen, Indigenous communities, and other community groups. By actively seeking and incorporating community feedback into revisions of the research plan, Subhas aims to ensure the research addresses priority concerns such as potential impacts on the marine ecosystem, saying he "cannot overstate how important this part of the project was...it was a huge lift" and,

> "It's made our science stronger and more relevant."

DR. MIJNDERT VAN DER SPEK
HERIOT-WATT UNIVERSITY

Assessing the performance of OAE pathways

To better estimate the performance assessment of OAE pathways, van der Spek, Dr. Phil Renforth, and their team developed a new technoeconomic analysis (TEA) and life cycle analysis (LCA) framework specifically tailored to oCDR technologies like OAE. This is the first time such a rigorous analysis has been applied to OAE.

This new framework represents a "first-time-right" approach rooted in technology market adoption theory. It also extends beyond traditional TEA and LCA frameworks by integrating locational and temporal dimensions such as climate change, energy transition, and place-based constraints. The framework is designed for ex-ante ("before the fact") evaluation of CDR, addressing variations in methodologies and uncertainties in supply chains, policy, costs, and environmental impacts.

Using this framework, the team completed a case study on bipolar membrane electrodialysis (BPMED; a process for producing NaOH) and showed how costs and climate impacts vary with location, design, and over time, as deployment scales and technology matures. Early findings highlight that costs initially rise with scale-up before falling, contrary to common startup assumptions. Van der Spek indicated that it's normal, saying,

> "It's the reality and we need to embrace that reality."

At a gigaton scale, technology will be cheaper.

Four additional OAE case studies are underway and will be used to further refine the framework. These include coastal enhanced weathering, ocean liming, hydrated carbonates, and buffered accelerated weathering of limestone. The outcome of this work is expected to better inform investment, research, planning, and policy decisions and be adaptable to other CDR pathways.

Exploring Diverse Stakeholder Perspectives

DIANE HOSKINS
CARBON TO SEA

Panel Session Overview

In support of advancing responsible OAE field research, this session focused on surfacing diverse priorities from supply chain actors, NGOs, governments, and buyers. Hoskins highlighted that Subhas' OAE field trial and permit success set a high bar for environmental safety reviews and community engagement. Hoskins said, "The critical path for conducting in-water research can truly not be divorced from the deep and time-intensive community engagement and political engagement efforts, which can make or break your project at the R&D stage."

This session sought to explore the role and perspectives of several non-academic entities that will help shape OAE research priorities, responsible paths forward, and decisionmaking. There are many different communities that are poised to engage with oCDR and OAE research, and they all have different priorities, networks, topics of interest, missions, and entry points. As such, integrating their perspectives enables and enriches scientific research.

DR. FRAUKE KRACKE
FRONTIER CLIMATE

Evaluating OAE from a carbon market perspective

Kracke provided an overview of Frontier Climate's advanced market commitment as a means to stimulate development of CDR. Frontier aims to buy over $1.25 billion of scalable and permanent carbon removal by 2030. To date, $551.3 million in pre-purchases and offtake agreements have been made, representing nearly 1.5 million tonnes of CO_2. The Frontier team uses eight criteria to evaluate technologies and guide investment decisions: durability, physical footprint, cost, capacity, net negativity, additionality, verifiability, and safety & legality. In addition to these criteria, for oCDR, Frontier especially values ecosystem safety, evidence of co-benefits, and community engagement. Kracke indicated Frontier looks for oCDR "deployments that de-risk cost [and] MRV, build social license,... and put ecosystem safety first." Frontier is only considering abiotic oCDR approaches and has purchased from four OAE and three direct ocean removal (DOR) companies.

During the panel discussion, Kracke explained that when it comes to pricing, Frontier focuses on the price point at scale saying,

> "We are comfortable with paying a higher price today...to build trust and reduce uncertainties, but there needs to be a way to see the cost effectiveness in the future."

She also highlighted the importance of academic collaboration with commercial entities to help build public trust and a need to focus research on co-benefits (e.g., ocean acidification relief).

DR. SIMONE H. STEWART
NATIONAL WILDLIFE FEDERATION

Centering communities, trust, and transparency in oCDR research plans

The National Wildlife Federation (NWF) is one of the U.S.' largest conservation organizations addressing wildlife recovery, climate solutions, and environmental justice. As part of their climate solutions focus, NWF works with conservation advocates, local and federal government, Tribes, and frontline communities on CDR. To date, most of NWF's work has focused on terrestrial CDR. Stewart explained how NWF engages communities, recognizing that the definition of a "community" is fluid, and different communities will have different priorities such as an outcome (e.g., reduced harm, ownership) or process (e.g., the right to say "no," data transparency). Relevant to oCDR and OAE, Stewart explained that decision making by communities is influenced by factors that influence public perception: technology, people, place, and process. In support of the latter and as part of NWF's engagement on oCDR, Stewart announced the publication of "Informing Marine Carbon Dioxide Removal Projects: Best Practices Guidance for Tribal and Indigenous Engagement."

During the panel discussion, Stewart touched on the tension between academic independence and the value of industry partnerships, saying that "where the money comes from, even if it comes from the federal government, means something to people." Stewart cautioned academics engaging with communities on oCDR away from thinking of themselves necessarily as "an independent third party, because a lot of times the public does not see it that way." A bright spot for Stewart is that more groups are getting involved in the oCDR field. She also shared thoughts on the need for a centralized communication and mission of oCDR from her work on terrestrial CDR technologies. Stewart drew a parallel between the many oCDR approaches and the varied terrestrial approaches, arguing that,

> "To have a centralized discussion around what it means to do terrestrial CDR is something that we've gotten to build up over time...I'm starting to see marine CDR go along the same trajectory."

DEREK BROCKBANK
COASTAL STATES ORGANIZATION

The role of coastal states in U.S. oCDR governance

Brockbank introduced the audience to the Coastal States Organization (CSO) which is a nonprofit formed under the 1972 Coastal Zone Management Act (CZMA) to help U.S. coastal states and territories shape federal coastal policy. CZMA gives states the authority to review federal activities in state and adjacent waters if spillover impacts can be expected. CSO plays a key role in coordinating state efforts, providing policy guidance, engaging communities, and partnering with federal agencies and NGOs. Brockbank explained that including states early in oCDR planning is crucial to navigating regulatory pathways, engaging communities, and integrating environmental and social considerations.

During the panel discussion, Brockbank provided insight on state-level opportunities in the U.S. As U.S. states have authority over their waters and can review federal action off of their coasts, it's important for state legislators to be informed about oCDR and coordinate on state-level oCDR regulatory frameworks. Going beyond education, getting buy-in, and maintaining public support and advocacy for oCDR research will be important, as people often have an emotional connection with the ocean. Changing political winds can shape and change engagement strategies. Given the deprioritization of oCDR research by the federal government, a bright spot for Brockbank is that,

> "Innovation happens locally, at a city level, at a state level. Not getting federal support allows this community to focus on where innovation can happen."

DR. FATIMA VAHLSING
OCEAN CONSERVANCY

How an environmental advocacy group evaluates new approaches

Ocean Conservancy is a U.S. nonprofit environmental advocacy group working on ending plastic pollution, reducing climate change, and protecting biodiversity. The organization focuses on climate solutions that are evidence-based and scientifically-driven. Vahlsing shared that Ocean Conservancy is engaging in the oCDR space to support advancing research that will help determine whether oCDR can scale in a socially and environmentally responsible manner. Ocean Conservancy relies on four criteria to evaluate their support for ocean climate technologies: effectiveness and scalability, mitigation potential, comparison of mitigation potential to environmental impact, and Ocean Conservancy's potential value-add in advancing a technology. Vahlsing explained that OAE is still under evaluation, saying,

> "It's incredibly important to us that we determine whether or not we can scale OAE in a way that is responsible, environmentally and socially. We know more data is needed."

During the panel discussion, Vahlsing explained that "there is no perfect sausage-making process" for this evaluation, but that the team draws from academic literature, NGO publications, and international white papers. Vahlsing also discussed the challenge of accountability around oCDR projects and the need for tools such as regulations and a code of conduct. Vahlsing echoed the importance of community engagement and the need for a code of conduct that is co-developed with industry.

Scaling Challenges Faced by Industry

Session Overview

Scaling an OAE industry is no small feat. As Christoph Beuttler and Dr. Sylvain Delerce from Carbon Gap explained in opening remarks, early voluntary investors, such as Microsoft and Frontier, launched the CDR sector. However, the voluntary demand is insufficient to scale CDR to impactful levels on time, and OAE suppliers are still grappling with major hurdles as CDR must be cost effective, safe, and desirable. This session sought to capture the gnarly problems industries are facing as they aim to scale their technologies.

CHRISTOPH BEUTTLER &
DR. SYLVAIN DELERCE
CARBONGAP

Building a market for oCDR in the EU

Opening this session, Beuttler and Delerce introduced Carbon Gaps' approach to unlocking the compliance market in the EU. The three core approaches to scale CDR are short supply, drive demand, and develop governance and standards. Beuttler shared that Carbon Gap believes that driving demand is "the most important thing at the moment" and argued in favor of the need to unlock compliance markets to scale carbon removal. The team identified the EU as the best opportunity to scale oCDR demand due to its comprehensive climate policy and the EU's existing compliance market. The aim is to ensure policy makers have the best available science on OAE and DOR as they evaluate the first oCDR certification methodologies within the EU Carbon Removal and Carbon Farming (CRCF) certification framework. This is a first step on a longer journey to a potential integration into the EU compliance markets. Over the next few years, the team will coordinate with the oCDR community to support the CRCF process and develop OAE and DOR methodologies, socialize oCDR with EU policy makers, and work to unlock dedicated EU R&D funding.

DR. WILL BURT
PLANETARY

A call for cohesion in strategic OAE communications

Taking a bird's-eye perspective, Burt shared his concern that the OAE community's "hand wringing over a lot of different uncertainties [and] disagreement about what's important, is cast out externally," affecting policymakers, regulators, and buyers.

As an example, Burt noted a lack of contextualized messaging around environmental impacts of OAE, with most research to date focused on extreme exposures and not attuned to realistic OAE deployments. Burt also called for more applied science funding to interrogate real-world conditions, and coordinated communications to, as included on his slides,

> "Align on where we stand regarding quantification uncertainties and ecological safety, and [to] communicate this broadly and effectively."

DR. ALLAN ADAMS
AQUATIC LABS

Designing sensors for uncertain requirements

Aquatic Labs is developing carbonate chemistry sensors with the aim of achieving lab-grade precision in the field and producing auditable datasets for MRV protocols. A key challenge for this work is that the team is creating tools for a future oCDR industry whose structure and MRV needs are undefined. Adams pointed out that the key scales of spatial and temporal variability are still unknown and priorities for optimization are not yet defined, citing "it's hard to know what to build, it's hard to know what the requirements even are for the things we want to build."

On top of this, it's not clear "Who's paying for what? Who does what for whom? What's integrated where?" How oCDR will be implemented won't be determined "until long-term buyers...come in and completely restructure the industry." Choosing to accept these uncertainties, Adams and his team focus on the part of the problem they can grasp and work with: building in situ sensors that can produce real-time and auditable datasets.

DR. FLORIAN BRINKMANN
PLANETEERS

Working towards scaling with efficiency and low cost

A key challenge for OAE companies is to scale up fast and keep costs down. In two years, Planeteers has fine-tuned enhanced weathering technology from technology readiness level (TRL) 3 (demonstration in a garage-based lab) to TRL 6 (test deployments at waste-water plants). The process is fairly simple, with inputs of water, limestone, and CO_2 to a reactor and mineralized water as the output. However, Brinkmann cautioned, "Everyone who thinks scaling technology is not a problem, has never scaled technology."

In preparation to scale their technology, the team focused early efforts on identifying cost reduction opportunities such as improving energy efficiency and optimizing feedstock volumes. However, it wasn't until they deployed their technology in the field that they discovered the opportunity to recover unused feedstocks (gas and minerals). The team is now adapting their technology to recover lost feedstock to improve efficiencies. Brinkmann hopes that this solution will help their technology to "stay on track with a price prediction...to sell credits in the near future for lower prices."

DR. EDMUND HALFYARD
CARBONRUN

Scaling distributed alkalinity delivery

CarbonRun, a river alkalinity enhancement company, already operates at TRL 9 with active projects in Canada and is preparing a project in Norway. Despite this early success, the team is grappling with scaling challenges, matching and optimizing deployment locations with resource needs and local desirability. Halfyard explained the problem of relying on an undeveloped supply chain of limestone for CDR: while agricultural limestone is widely available, it is not always to the specifications CarbonRun needs, in terms of purity, particle size, and other factors. "The [limestone] supply chains don't... consider the carbon that's emitted. And so you can get cheap bulk material, but you really hammer on the [lifecycle assessment] side of the MRV," he said.

Another challenge is the reliance on a distributed production model. Different rivers have different communities. As the team builds out their operations, Halfyard said "we need to find ways to better tell the same story in different languages. And to do so, we really are trying to establish a robust process that has checks and balances...but also being flexible...to incorporate local information and knowledge" as the team also relies on local partners for support and data collection. Halfyard concluded, "A whole ecosystem built around CDR is not easily done, but that's a big challenge that's in front of us."

DR. STEPHEN ROMANIELLO & ZACH COCKRUM
VESTA

Balancing priorities to achieve responsible growth

On the heels of two successful field trials and methodology development for olivine-based coastal enhanced weathering, Romaniello defined Vesta's key challenge as how to responsibly and safely scale from a small pilot to a commercial deployment in a manner that incorporates the diverse perspectives of stakeholders such as those at the Carbon to Sea Convening.

Olivine dissolution is a function of temperature and grain size, and therefore, there are known optimal conditions for CDR. To date, Vesta prioritized field trials in areas outside of the optimal temperature and grain size conditions, in favor of prioritizing socio-political factors, such as willing communities, well-regarded regulatory frameworks, and available technical capacity. Moving towards commercial scale deployment will require factors that also optimize the CDR and MRV. Vesta tackles their scaling challenges by leveraging and partnering with existing industries (beach nourishment industry, olivine supply chain), engaging with buyers, and sharing their learning to inform policy and regulatory regimes, as they continue R&D.

DR. NOAH PLANAVSKY
YALE UNIVERSITY

Improving academic and public perceptions of OAE

Speaking from direct experience, Planavsky called for the need to better communicate OAE and introduced mangrove-based OAE as a high-leverage opportunity for public support. He highlighted a need to "improve perception [of OAE] from the academic community and broader public." Planavsky then introduced the idea of OAE through mangrove restoration and presented scientific evidence of alkalinity production by mangroves and model results demonstrating a scalable CDR potential. He encouraged the pursuit of additional research on mangrove restoration, as a pathway with already high social support due to biodiversity and fisheries benefits, as a means to "spur market activity and government-funded support of geochemical mCDR," Planavsky stated in his presentation slides.

Dr. Kim Stanley Robinson's Keynote Address

Robinson is widely acclaimed as one of the most influential fiction writers of his generation. He shifted his focus from envisioning space exploration in works such as the *Mars Trilogy* to the dire consequences of climate change and their possible solutions, in works such as *The Ministry for the Future*. Though his novels are fiction, they have inspired readers who see the work as meticulously thought out, possible roadmaps for the future.

Robinson's characters have crafted practical plans in the face of a looming crisis, and he shared inspiration and calls to action through his keynote address. He praised the OAE community for engaging in a bold and necessary effort to evaluate new solutions. He drew parallels to his own work, which has long explored novel technological approaches in fiction.

We are reaching an "all hands on deck" moment, said Robinson, where innovative carbon drawdown solutions must be responsibly developed from fantasy to reality. He described humanity's practice of burning fossil fuels for thousands of years as itself a form of "geoengineering," which is often a term used to describe many potential climate solutions. He proposed a reframing of OAE as a "restoration and repair project" and encouraged the field to consider how important it is to communicate in plain language. He praised OAE as potentially more safe, effective, inexpensive, and technically simple than other proposed CDR methods. Robinson also challenged "moral hazard" and cost arguments, noting that spending even a fraction of global GDP to save the biosphere, through projects such as decarbonization and carbon removal, is both rational and necessary.

Robinson encouraged the OAE community to "work as one" to pursue public education and communicate the advantages of OAE.

When asked about balancing desperation and pragmatism, Robinson urged the audience to retain hope and focus on collective and local action. He emphasized solidarity, storytelling, and scenario-modeling as tools for inspiring public engagement.

> "Teach in a larger community, that's the best you can do," Robinson said, and echoing words by Dr. Robert Kopp from Rutgers University, "convey the idea that 'every tonne counts'."

Major Announcements

The OAE community continues to grow rapidly. Eleven oCDR organizations announced the launch of several new programs, products, and services. Collectively, these activities support the scaling of transparent research, enabling industry growth, and improving knowledge sharing and coordination in the oCDR field. There are several entry points into these new projects and numerous calls for engagement.

Improving Coordination & Synthesis

RUTH DRISCOLL-LOVEJOY
OCEAN VISIONS

oCDR Collective Strategy Project

As a response to a growing field of oCDR activities requiring consistent coordination and additional collaboration, Driscoll-Lovejoy announced the progress made on the Ocean Visions “Building a Collective Strategy to Advance mCDR R&D for Climate-Relevant Solutions” project, which launched at the end of 2024. The project aims to develop a collective strategy to better coordinate action over the next five years and ensure that the oCDR field produces the evidence and data needed that will allow society to make sound decisions by 2030 about larger scale deployments. In the second half of 2025, Ocean Visions will publish a foundation setting report that identifies priority strategic areas, critical gaps, and proposed steps needed to draft clear milestones for the field to accelerate R&D. The report will support development of the collective, actionable strategy for the oCDR field.

NICK KLEINERT
CARBON TO SEA

Global OAE Field Research Network

Kleinert announced the launch of Carbon to Sea's Global OAE Field Research Network. The vision for this network is to help prioritize R&D questions, share learnings, channel funding, and publish data. This initiative is a response to the growing risk of knowledge fragmentation and uneven built capacity as OAE research grows in the field. To inform the design of this network, Carbon to Sea published an open Request For Information (RFI) and invites OAE researchers and representatives of potential field sites to answer a few questions on ambitions, traction, and research priorities.

The RFI will be followed by a Request for Proposals in the fall of 2025. Applicants can apply for funding to establish new research sites and join the Global OAE Field Research Network.

KELLY OSKVIG
NASEM

NASEM Marine Carbon Dioxide Removal Standing Committee

Oskvig announced the launch of a NASEM Marine Carbon Dioxide Removal Standing Committee tasked with updating the report "A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration," published in 2022. The first update is scheduled to be published in early 2026 and will focus on OAE. The resource will be available in digital format and aims to serve the broad oCDR community with an objective and evidence-based resource on the state-of-science, as well as continue to identify the most urgent research needs in the field.

The committee is composed of expert volunteers who will be announced soon and the first public meeting will take place in July. Oskvig highlighted several opportunities to engage with the committee, including public meetings and peer-review processes. Carbon to Sea provided the initial grant for the project.

ERIC SIEGEL
OCEAN FRONTIER INSTITUTE

mCDR COMPASS

Siegel announced the launch of mCDR COMPASS, an initiative to advance the responsible and equitable development of the oCDR sector in Canada. Five postdocs will be hired to coordinate, integrate, and resource expertise and activities as well as to advance the sector through intentional collaboration across science and data, policy, community engagement, and business strategy. Initial research priorities include the co-development of adaptive regulatory pathways from pilot-scale to full-scale deployments, assessment of the legal basis for community benefit sharing agreements and associated financial assurances, and development of frameworks for free, prior, informed consent and co-ownership models with Indigenous communities.

Siegel invited additional engagement and partnership from groups working on communication, community engagement, regulatory development, and business/market development.

Unlocking Markets & Policy

ANU KHAN
CARBON REMOVAL STANDARDS INITIATIVE

Carbon Removal Standards Initiative entrance to OAE

Over the next 24 months, Carbon Removal Standards Initiative (CRSI) aims to identify policy mechanisms, ideas, and opportunities to help scale CDR, including OAE, via industrial integrations. As a non-profit entity working on CDR quantification policy, CRSI aims to scale CDR activity by strategically working alongside voluntary and compliance carbon markets through "complimentary policy packages" to motivate, fund, and measure CDR technologies.

Khan explained that her team is eager to expand from their work on enhanced weathering and invited the OAE community to share relevant policies (e.g., subsidies and regulations) the field has encountered, as well as new opportunities and "wacky ideas," to support the potential scaling of OAE as a climate solution.

ERIN BURNS
CARBON180

U.S. Ocean Policy Initiative

Burns announced the launch of Carbon180's new Ocean Policy team, marking the expansion of the organization's focus from land and technological carbon removal to oCDR. Carbon180 recently hired Dr. Amanda Vieillard to lead their ocean policy work, which will focus on:

- Expanding U.S. federal policy on oCDR, including R&D at the Department of Energy and the National Oceanic and Atmospheric Administration, as well as through less traditional routes (e.g., the Farm Bill)
- Building capacity for engagement in oCDR by coastal communities via a regranting program
- Catalyzing state-level action on oCDR
- Working across the oCDR ecosystem on shared MRV challenges

NOAH DEICH
ROCKY MOUNTAIN INSTITUTE

Global CDR Advanced Market Commitment Project

Thinking big about what CDR will look like over the next century, Deich announced the Global CDR Advanced Market Commitment Project to bring governments together globally to collectively pledge billions of dollars for new demand for CDR in the next five to ten years. Assuming CDR won't happen at a price point above $100 per tonne of CO_2, the theory of change of this project is that government investments can pull forward innovation and send a signal to the market and crowd in voluntary purchasing support. While this strategy assumes CDR will emerge as a market, Deich pointed out that oCDR "doesn't have to work as a carbon credit-driven framework." He also encouraged the OAE community to come to a consensus on a vision for scaling the field, noting that "we need to move out of the R&D phase far before we are comfortable as a community to do that."

EMILY ROGERS
THIRD DERIVATIVE

Demystifying MRV and assisting oCDR startups

Rogers announced two activities whereby Rocky Mountain Institute and its accelerator, Third Derivative, will become more deeply engaged in oCDR.

First, Third Derivative has partnered with [C]Worthy to publish a white paper about the oCDR MRV process. This work aims to demystify the steps required for sufficiently rigorous MRV and ultimately inform investment in oCDR projects. The paper is expected to be published by early July.

Second, as Third Derivative's role is to rapidly find, fund, and scale climate tech globally, Rogers also announced plans for new support tailored to the opportunities and roadblocks faced by oCDR startups (e.g., navigating the permit process, identifying business models, and accessing new forms of capital and potential project partners). The team is seeking partners and funders for an oCDR-specific program, and those interested can reach out to learn more.

DR. SOPHIE GILL
ISOMETRIC

Issuance of the first OAE credits

Gill announced that Isometric is issuing the first-ever verified OAE credits for Planetary's deployment in Nova Scotia. As a registry, Isometric's role in this achievement was to provide the carbon removal protocol, coordinate third-party verification by 350Solutions, and transparently surface and display the quantification of these credits. The credits are expected to be issued in a few weeks. Gill's call to action was to take a look at the data and share feedback to improve the OAE protocol, emphasizing Isometric's priority to innovate and learn from deployments.

Developing Research Tools

DR. ALICIA KARSPECK
[C]WORTHY

MRV modeling tools

Karspeck announced the upcoming publication of two model resources to build the foundation for responsible carbon removal.

First, [C]Worthy launched the Direct Ocean Removal (DOR) Atlas in June. The dataset is expected to provide transparent and region-specific insights and is similar to the current OAE Atlas, which has supported OAE research and investment, project siting, carbon removal estimates, and policy analysis.

Second, [C]Worthy plans to release C-Star, a modeling tool to support oCDR research and quantification of carbon removal, in December 2025. Version 1.0 of the C-Star regional modeling system aims to support site-specific carbon removal quantification in the Pacific and Atlantic. It will generate fully documented outputs and audit trails designed to meet the needs of registries, verifiers, and developers, to advance trustworthy accounting for oCDR.

DR. GRACE ANDREWS
HOURGLASS CLIMATE

FEMM: Framework for Ecotoxicological Modeling mCDR

To advance rigorous science on environmental impact quantification on OAE, Andrews announced the development of a framework for ecotoxicity modeling. Framing the motivation for this work, Andrews explained that the oCDR field has “poured tons of resources into nailing down and bringing down the error bars on carbon quantification; I think we should be doing this for environmental impacts, too.” The Framework for Ecotoxicological Modeling of mCDR (FEMM) is “designed to elevate the rigor, but reduce complexity, of implementing environmental impact assessment for mCDR projects.” It has use cases for oCDR project planning, permitting, and MRV, and its predictive capability will help project developers select low-impact sites and deployment strategies while following existing, related regulatory standards.

FEMM will undergo a public comment period through July, and the beta version of the web tool will be released in the following months.

Carbon to Sea Initiative

Workshops

To leverage the collective breadth of expertise amongst the participants and opportunity for co-design of OAE R&D, the second day of the Convening consisted of four topical workshops: MRV, environmental impact assessment, community engagement, and coordinated field research. Participants were able to join two of the four workshops. The workshops aimed to share insights, feedback, and new ideas on OAE R&D priorities. The discussions will be used by Carbon to Sea to identify shared priorities that will form the foundation for future programs, grants, and other activities.

Assessing OAE MRV Readiness & Improvement Opportunities

Overview

To enhance monitoring at field research sites, Carbon to Sea is proposing a new funding program. The aim of this workshop was to explore program priorities on measurement, modeling, statistical analyses, and incentives to close uncertainty gaps in CDR quantification, reduce ambiguity of current MRV requirements, and accelerate learning through broader data sharing.

To set the stage, Dr. Veronica Tamsitt and Dr. Mike Tyka outlined modeling approaches from near-field to global scales, emphasizing how uncertainty arises and might be addressed. Dr. Will Burt shared lessons from the first OAE credit issuance process via Isometric, underscoring the financial and operational difficulty of sustaining scientifically useful measurements not required by current protocols.

Workshop participants, grouped by academia, the voluntary market, and future compliance markets, then held breakout discussions to brainstorm program priorities for improving uncertainty and error quantification as well as informing future MRV requirements.

Outcome

Overall, participants expressed strong enthusiasm for the concept of a dedicated funding program to address the current challenges in MRV, with a top priority of providing additional funding of measurements during field trials. The groups shared specific priorities:

- **Academics** prioritized reducing scientific uncertainty by increasing baseline and far-field observational capacity; leveraging natural analogues to inform key processes that need to be represented in models; and identifying strategies to allow comparison and standardization of measurement approaches at research projects and increasing commercial scales.

- Representatives of the **voluntary market** emphasized easing buyer anxiety and reducing ambiguity of MRV requirements. While model and measurement uncertainty could be addressed through funding additional monitoring at commercial field sites, this group also identified the need for more independent data-driven storytelling and engagement around these uncertainties.

- **Compliance market** conversations centered around higher-order questions that will be critical to address for future integration assessments by governments and policymakers. These groups identified additionality, conservative uncertainty discounts, and understanding of environmental impacts and co-benefits as core priorities to be considered in future MRV frameworks that could be ideally addressed via long-term monitored field trials across multiple different deployment sites.

The three sectors agreed on several priorities. First, there is a need to develop common measurement strategies. This could be accomplished with dedicated interdisciplinary working groups to develop specific research priorities and statistical analyses that are aligned with market needs. Second, OAE communication efforts need to better address the role of measurements and models and demystify the quantification process. The program could develop storytelling using real-world data to reduce buyer anxiety and build social license. Third, environmental impacts remain a priority. The group recommended funding dedicated to evaluating ecosystem and co-benefits, possibly through natural analogues, and extending baseline data collection.

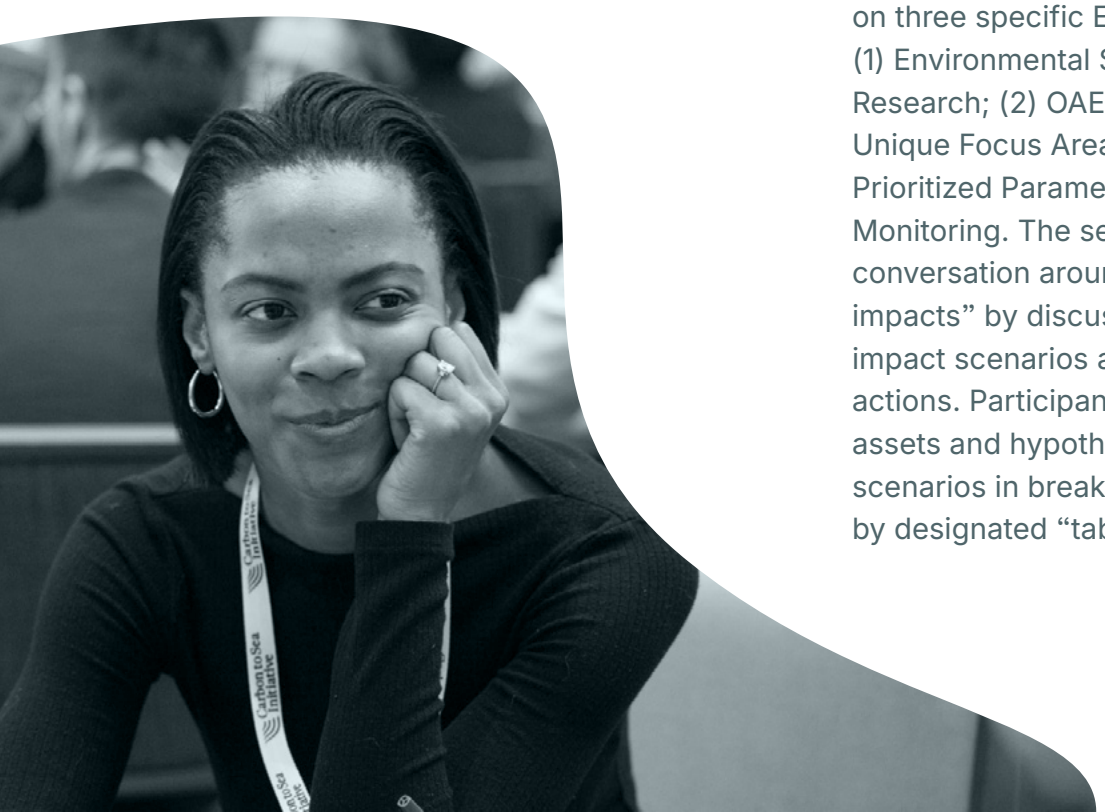
Next step

Carbon to Sea will continue to analyze the workshop findings and prioritize categories of need and broader learning goals. Further refining potential program design and working towards shared MRV priorities will likely involve the creation of several working groups over the next three to five months. For further details on the outcomes, progress updates, and questions around next steps, please contact Anna Madlener at Carbon to Sea.

Preview: Environmental Impact Monitoring Framework for OAE

Overview

Ensuring rigorous environmental monitoring and robust evaluation of any potential impacts on marine wildlife is critical input to the trade-off analysis that society must consider alongside any future OAE adoption. Carbon to Sea partnered with Plymouth Marine Laboratory (PML) Applications to develop a community-led Environmental Impact Monitoring Framework (EIMF). This workshop previewed key components and assets with the Convening's participants, while seeking their feedback.



The EIMF intends to align OAE practitioners and decision makers on an approach for environmental impact monitoring of OAE fieldwork covering a range of OAE pathways, and at increasing scales over time. The draft framework was developed through expert interviews, workshops, and additional solicited feedback in the spring of 2025.

The first aim of this workshop was to share the goals and intentions of the EIMF with the workshop participants and gather feedback on three specific EIMF assets that described: (1) Environmental Stage Gates of OAE Field Research; (2) OAE Method Definition and Unique Focus Areas for Monitoring; and (3) Prioritized Parameters for OAE Environmental Monitoring. The second aim was to begin a conversation around "tolerable environmental impacts" by discussing a range of hypothetical impact scenarios and potential mitigating actions. Participants discussed the three assets and hypothetical environmental risk scenarios in breakout groups, facilitated by designated "table captains."

Outcome

Structured to encourage constructive feedback, the discussion involved numerous recommendations for improving the three EIMF assets. Feedback highlighted a desire to better reflect the dynamic nature of developing a fit-for-purpose environmental monitoring plan. Participants mentioned how variable and influential project-specific details (including feedstock, discharge location, and scale of impact and local ecosystem) can be when determining the environmental risks. Practitioners with field experience shared insights from the iterative engagement that currently exists when designing and regulating OAE projects as well as the need for local community engagement. They also provided specific commentary on the utility and practicality of various parameters and activities.

The environmental risk scenario-planning portion of the workshop included scenarios wherein either OAE field operations experienced an abnormal observation or increased uncertainty (e.g., sudden decline in chlorophyll observations, shift in phytoplankton community, or crab migration out of the project area). All participants brought their unique perspectives to the discussion, and impact "tolerance" varied depending on the scientific value of the research finding, the short-lived or reversible nature of the impact, or the relative size of the spatial scale. Participants voiced less tolerance when considering similar monitoring conditions under long-term, commercial OAE operations. Given the highly variable nature of a dynamic ocean, it is difficult to attribute some impacts to a trial's activity. In many cases, participants recommended additional monitoring to better isolate the origin of an observed impact to inform decisions on whether and how to change trial operations. The exercise revealed that tolerance of an environmental impact is influenced by the project's approach, purpose, length, and anticipated knowledge gain.

Next Step

Carbon to Sea and PML Applications will review workshop feedback and insights to inform a revision of the EIMF, which will be released for another comment period in the summer of 2025. Comments and their associated resolutions will be published on the Carbon to Sea website along with a final document, which will continue to evolve as the field's knowledge base expands and consensus builds.

Community Engagement

Overview

In recognition of the critical role that community engagement plays in advancing OAE field research, Carbon to Sea invited Tracey Brown to share her expertise and experience in designing and implementing public engagement programs around complex scientific topics.

Brown is the Director and co-founder of Sense about Science, an independent nonprofit that works to raise the standard of scientific evidence in public life and policy. She has been named of the most influential figures in science policy in the UK and her work has been adopted into UK ministerial code.

The workshop emphasized a structured and proactive approach to public engagement. Brown believes that it is important to invite community members into the decision-making process by transparently sharing uncertainties, limitations, and tradeoffs in the research. Instead of simplifying information or overstating certainty, Brown recommends fully explaining the dilemmas of a research question or roadblock and inviting community members to work through the challenges alongside the research team. This process fosters trust and stronger buy-in.

Brown made several recommendations on successfully engaging the public in a collaborative manner that can lead to greater support of scientific research:

- Engaging the public early and collaboratively in the planning process is crucial for building trust and understanding, rather than doing outreach once research is already underway.
- Providing opportunities for ongoing dialogue and input from the community, rather than one-time consultations, helps build relationships and shared ownership.
- It is important to understand the local context, history, and concerns of communities that may be impacted by the research.
- Framing the rationale and goals of the research in terms of addressing local issues and concerns, and creating community co-benefits — rather than just the broader scientific objectives — can help increase relevance and buy-in.
- There is no universal formula for community engagement. The only guarantee is that, if you hold back information from the public, you will sow distrust.

Participants in the workshop were then divided into smaller groups and asked to consider what a community would need to know in order to consider a proposal to conduct OAE field research.

Outcome

In sharing their findings from the exercise, several common suggestions for engagement priority and approaches emerged:

- When explaining the project, care should be taken to explain the proposal in clear terms. This is particularly important for research related to something as culturally and personally important as the ocean; researchers should explain early and clearly what is being added to the ocean and why.
- Terms such as “ocean alkalinity enhancement” should be thoroughly explained and potentially rephrased to be more accessible. Analogies should be used to explain complex science in relatable terms.
- Scientific uncertainties should be transparently and honestly explained.
- Emphasis should be placed on the local impacts of climate change as well as the possible impacts and benefits of the project.
- Community members should be invited to shape the project with a level of engagement that is deeper than simply being informed of existing plans.

Next step

SeaCURE and Brown will use insights from this workshop to inform upcoming engagement with community members involved near the SeaCURE site in Weymouth, UK. This work, funded by Carbon to Sea, will result in a community engagement framework for OAE, a resource that could help field research across the globe.

Coordinated Field Research

Overview

As the number of OAE field studies and deployments grow, it is critical that the OAE community aligns on the priority unanswered questions and share learnings. To address this need, Carbon to Sea is preparing to launch a “Global OAE Field Research Network.” The aim of this workshop was to build consensus on (1) what must be studied and (2) what type of collaboration activities should be funded.

To address the first aim, participants broke into breakout groups and were given one of five R&D categories — feedstocks, environmental monitoring, measurement & modeling, community engagement, or scalability — and asked to develop a list of priority research questions for the field. They then sorted questions by the field trial stage needed to answer each question (i.e., planning & preparation, methods validation, OAE field pilot, and continuous dosing & monitoring stages). To address the second aim, participants ranked 32 potential network features (and wrote in some of their own) as “must have,” “nice to have,” or “lower priority.”

Outcome

For the field research agenda, 113 different research questions were identified, then sorted by R&D category and field research stage. By stage, 27 questions mapped to planning & preparation (before any alkalinity is added), 24 questions were mapped to methods validation, 34 to OAE field pilots, and 28 to continuous dosing and monitoring. By R&D category, 23% of questions addressed feedstocks, 24% environmental impacts, 23% measurement & modeling, 17% community engagement, and 13% scalability. Examples of these questions included “What parameter space keeps mineral feedstocks off the sediment?” and “Can we constrain the carbonate budget at the edge of the mixing zone at a reasonable cost and correlate with the addition of alkalinity?”

In the second exercise, participants ranked a total of 35 network features. Thematically, “must have” features tended to be ones that standardized, prioritized, and performed intercomparisons for OAE research such as commitment to common metrics; the standardization of data frameworks; conducting

multi-trial analyses and intercomparisons; and defining a shared R&D agenda. Network features that involved the creation of new intellectual property or knowledge (such as maps, calendars, toolkits, and training programs) were more often ranked as “nice to have.” Features such as physical asset sharing, staff or resource sharing, and imposing network-wide governance were rated “lower priority.” There was generally a lower standard deviation of rankings (<6) for features that were “must have” and “lower priority,” and higher standard deviations of rankings (i.e. less agreement) on the “nice to have” features that fell in the middle. The “equity & benefit sharing guidelines” feature, for example, had the highest disagreement in ranking, with the community engagement focused breakout group ranking this feature highly while others placed lower emphasis on this feature.

Next Step

Carbon to Sea will review the prioritized research questions to inform a Coordinated Field Research Agenda. This agenda will then be used to inform Carbon to Sea grantmaking in the coming one to two years. Outcomes from the network feature exercise will shape the Global OAE Field Research Network that Carbon to Sea intends to grow over the next few years.

Hill Day

At the conclusion of the Annual Convening, the Carbon to Sea team was joined by several grantees and partners for the first-ever Hill Day event. Participants met with several Members of Congress and over 60 Congressional staffers representing Republican and Democratic districts across the U.S. to raise awareness around oCDR research and development.

The group was able to answer questions from Congressional staff from both parties recognizing the potential economic and environmental benefits of oCDR. Participants shared the latest information on the state of the science for oCDR approaches and discussed key policy opportunities to shape and support the emergence of a responsible and high-integrity field.

Carbon to Sea’s first Hill Day visit marked an important step in growing awareness of oCDR science and policy opportunities.

Abbreviations

BPMED	Bipolar membrane electrodialysis
CDR	Carbon dioxide removal
CO_2	Carbon dioxide
CRSI	Carbon Removal Standards Initiative
CSO	Coastal States Organization
CZMA	Coastal Zone Management Act
DIC	Dissolved inorganic carbon
DOR	Direct ocean removal
EIMF	Environmental impact monitoring framework
EPA	Environmental Protection Agency
EU	European Union
FEMM	Framework for Ecotoxicological Modeling of mCDR
Gt	Gigatonne, a unit of mass equal to one billion metric tons
IPCC	Intergovernmental Panel on Climate Change
LCA	Life cycle analysis
mCDR	Marine carbon dioxide removal, also referred to as “oCDR”
MRV	Monitoring, reporting, and verification
NaOH	Sodium hydroxide
NASEM	National Academy of Sciences, Engineering, and Medicine
NGO	Non-governmental organization
NWF	National Wildlife Federation
OAE	Ocean alkalinity enhancement
oCDR	Ocean-based carbon dioxide removal, also referred to as “mCDR”
pCO_2	Partial pressure of carbon dioxide
PML	Plymouth Marine Laboratory
R&D	Research and development
RFI	Request for information
TEA	Technoeconomic analysis
TRL	Technology readiness level
WHOI	Woods Hole Oceanographic Institution

Carbon to Sea Initiative

CarbonToSea.org

For More Information:

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