OCEAN VISIONS

Research and Development Project

Phytoplankton Carbon Solutions

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27 March 2024

Agenda

- Introductions 11:00-11:05
- Plenary Project Summary 11:05-11:20
- Breakout Working Groups by Theme 11:20-12:15
  - Theme summary and draft goals
  - Key research questions
  - Phase 3 activities
  - Ongoing work
- Reconvene Plenary 12:15-12:25
  - Group reflections
  - Summary
- Project Next Steps and Adjourn 12:25-12:30

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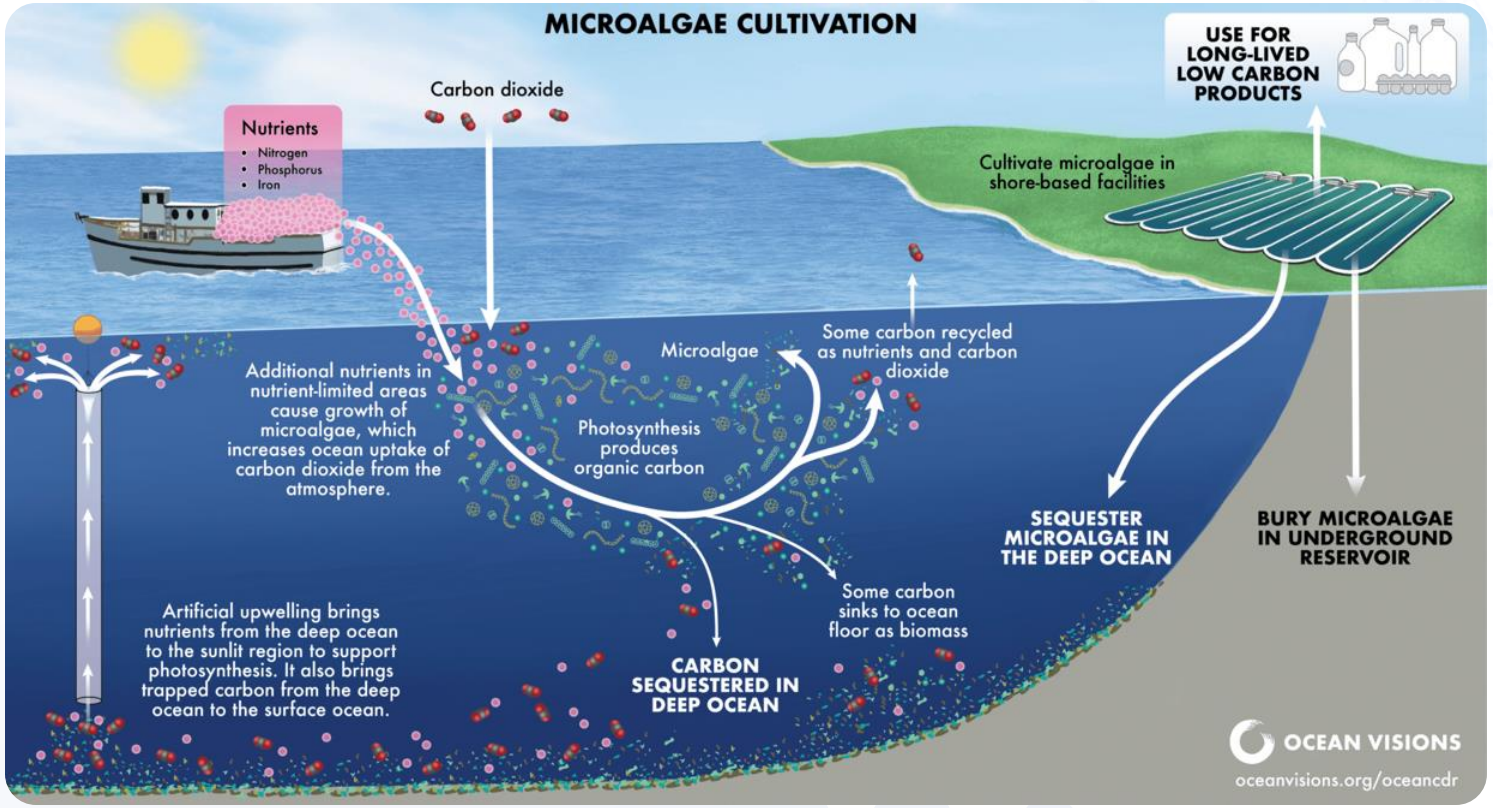
Phytoplankton Carbon Solutions (PCS)

Definition

Marine carbon dioxide removal approaches that aim to boost the ocean's primary productivity of microalgae and the biological pump that moves some portion of that additional biomass into the deep ocean.



Source: Ocean Visions

WHY PCS pathways?

- Negative emissions are a part of every long-term climate strategy
- A wide range of CDR strategies are in use or under development
- All have various scaling potential, cost, material and energy inputs requirements, and environmental and socioeconomic implication
- Based on previous field research, PCS have been shown to have a high potential to scale with relatively low energy and material inputs
- Now is the time to fully test and understand the range of issues that might come into play in the future

WHY this Project?

- There is renewed interest in PCS as a potential CDR solution within scientific and philanthropic communities
- There is a need for comprehensive approach and careful consideration of PCS pathways as a CDR solution
- Now is the time to plan, strategically, the critical scientific knowledge needed to inform decisions on PCS
- Additionally, decisions will benefit from a structured and inclusive process that considers scientific and socioeconomic needs together rather than sequentially

WHAT is this project?

- A short-term effort to **design** -- by late summer -- a proposed five-year Research and Development program to guide future investments

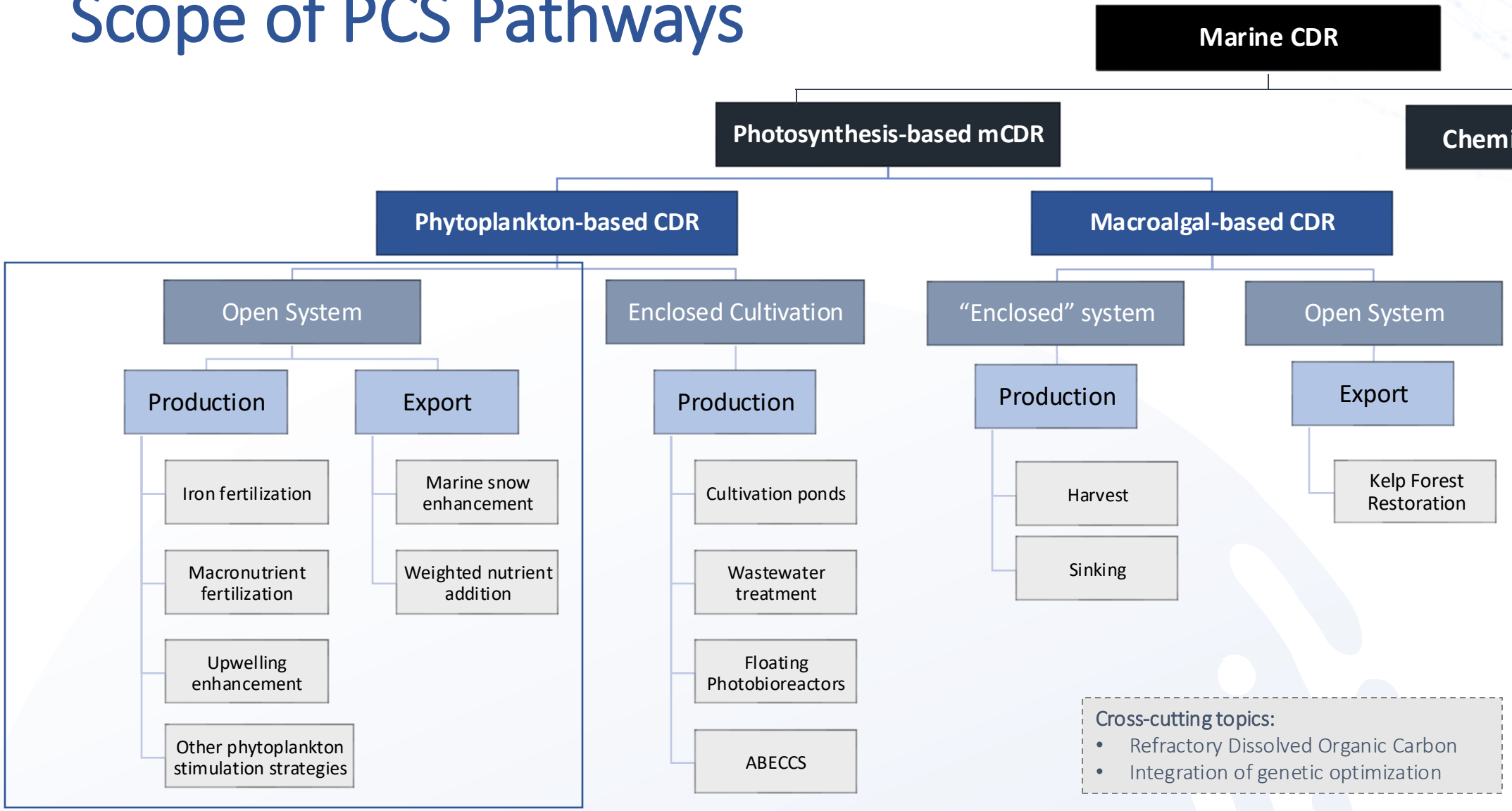
- Focused on ocean strategies to stimulate phytoplankton growth as a carbon uptake and sequestration tool

- Help shape the research agenda that will enable societal decisions about future use of these PCS pathways both alone and in relation to other CDR opportunities

- Considers and builds on the wide range of work already underway

- Seeking to build greater focus on the pathways of greatest potential and the priority work needed to inform future decisions

Scope of PCS Pathways



Source: OV Roadmaps, CEA

The Project's ‘universe’ of topics

Benefits
- Durability
- Scaleability
- Measurability
- Safety

Environmental Risks
- Oxygen depletion
- Nutrient robbing
- Harmful algal blooms
- Direct habitat impacts

Socio-economic Risks
- Direct economic
- Indirect economic
- Health
- Regulatory

Cross-cutting mCDR Needs
- Understand baseline conditions
- MRV capacities and approaches
- Ocean observation and modeling
- Environmental risk assessment
- Community engagement
- Communications
- Governance

Sectors
- Scientific
- Engineering
- Social
- Political
- Economic
- Legal
- Governance

Scales
- Site
- Regional
- Global

PCS Project Plan

Phase	Key Activities and Deliverables
Phase 1: Define project focus *October – December 2024*	▪ Develop project logic framework ▪ Develop taxonomic focus ▪ Phase 2 Research Plan ▪ PCS webpage
Phase 2: Research & Program Design *December 2024 – March 2025* **WE ARE HERE**	▪ Desktop research / Landscape Assessment ▪ Focus on the work already underway ▪ Develop draft R&D Program ▪ Phase 3 Engagement plan
Phase 3: Feedback & Revision *March – July 2025*	▪ Attend conferences, conduct expert interviews ▪ Second Draft R&D Program ▪ Scope & recommend limited grantmaking to inform final recommendations
Phase 4: Final Recommendation *July-August 2025*	▪ Final R&D Program Design ▪ Public-facing materials

[Draft] Goals & Priorities

Developing R&D Priorities

Ten Year Goal:

In 10 years develop an adequate understanding of the risks and benefits of PCS pathways. Enable societal decisions on these pathways as potential solutions, alone and compared to other mCDR or CDR pathways, with focus on international agreement

Note: Any future consideration of employing these pathways would only proceed in addition to and following sufficient mitigation of fossil fuel pollutants.

Five Year Goal:

Prioritize and support the right research and development (R&D) work to adequately inform decisions on continued development of PCS toward the ten-year goal

Note: All materials presented here today are DRAFT to stimulate discussion and support further development and refinement of the R&D program.

[draft] Ten Year Target

Be in position to know on whether PCS should be part of the global CDR portfolio, including:

Durability. PCS pathway carbon benefits can be sustained on the level with or better than other CDR approaches.

Scalability. PCS interventions are confidently confirmed to be capable of achieving more than one Gt CO_2 scale in defined ocean regions.

Measurability. MRV methods are comparable to other CDR pathways and yield clear delineation of carbon benefits. Execution costs, including energy expenditure are quantified.

Safety. Clear understanding of environmental and socio-economic risks enables full risk / benefit consideration.

[draft] Five Year Target

Have completed or underway high priority R&D work to inform the decision to continue PCS R&D towards the Year 10 target, including:

Durability. PCS and locations that maximize durability are known and uncertainty of PCS durability potential has been reduced.

Scalability. Uncertainty in the realistic scalability of different PCS approaches has been reduced.

Measurability. In field & model-based MRV methodologies have been advanced and provide moderate-high confidence insight on durability and cost of PCS.

Safety. Knowledge of environmental and socioeconomic risks have advanced sufficiently to enable decision-making on the continuation of PCS R&D.

[draft] What is needed to achieve these goals?

Monitoring, Reporting and Verification – Can PCS pathways yield **durable** carbon benefits, and can we sufficiently and quantifiably **measure** cause and effect? Can cost of implementation be developed for sufficient comparison with other CDR opportunities?

Environmental Impacts – Can we gain sufficient knowledge about environmental and socio-economic risks to effectively inform future societal cost/benefit decisions? This scoping includes both test sites and broader regional or global impacts.

PCS Pathways and Innovations – What PCS pathways and other innovations should be prioritized as a focus of a R&D program?

Inclusive decision-making – As PCS pathway, MRV, and environmental impact understanding improves, what governance, community engagement, and other steps are required – both for field trials and potential future scaling – to effectively move forward?

Nuts and bolts of program management – What are the key elements of a future R&D program needed to ensure progress? These include priority management, funding decisions and alignment, communications, coordination across the landscape of other CDR / mCDR opportunities, and identification and adherence to off-ramps.

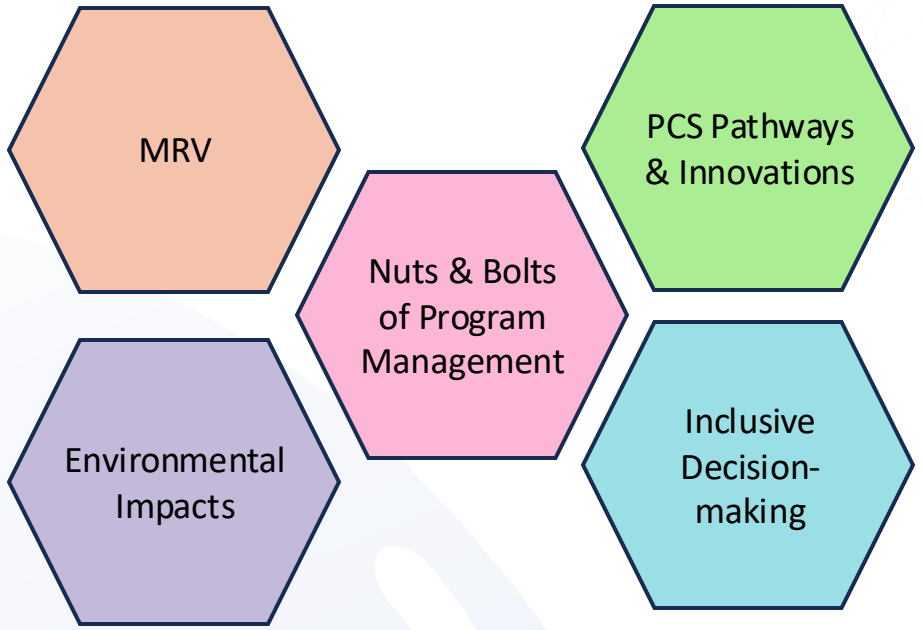
Next Steps

Over the next six months we will:

- **Further define, test and refine key research questions** on durability, measurability, scalability, and safety

- **Develop a five-year R&D strategy** to answer those questions by:
  - Leveraging and building on ongoing research and expertise
  - Conducting further testing and expert interviews
  - Identifying and refining research and development priorities
  - Commissioning short term workshops and other focused work on key topics

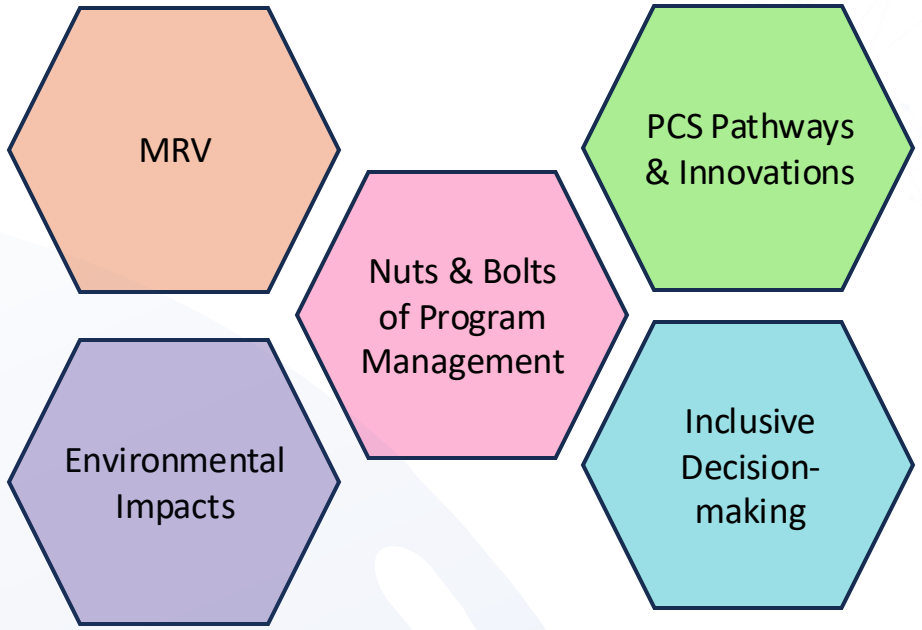
- **Outline the operational program management approach** to ensure inclusive and informed decision-making can be achieved with the research outcomes at the 5-year stage gate.



Next Steps TODAY

We will move to breakout groups to:

- **Ask questions and provide additional general comment on this project**
- **View and provide additional input on goals of this R&D design project**
- **View and provide additional perspective on key research questions**
- **Consider short term actions (next three months) that could further inform the R&D program**
- **Further identify ongoing work for consideration**



Breakout Groups

We'll come back from breakout groups at 12:15.

You can share feedback directly with the PCS project team by using the QR code.

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MRV: Goal & Objectives

Five Year Goal: Demonstrate the ability to achieve **high confidence MRV** methodologies and use these to **quantify the durability** of priority PCS pathways.

- **Identify and prioritize ocean regions and PCS pathways** that harbor durable and scalable and cost-effective potential for PCS
- **Identify, define, and reduce uncertainty** (to acceptable levels) in variables with greatest influence on durability and identify show-stopping impacts and / or insurmountable levels of uncertainty
- **Improve MRV and model capabilities** to sufficiently predict, observe, and reproduce PCS perturbations
- **Ensure MRV approaches** are consistent with other CDR pathways and ensure that cost considerations – including energy expenditures for implementation – are well understood

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MRV: Key R&D Questions

- **What factors drive uncertainty in understanding PCS carbon impact and which component parts require priority attention?**

- **What natural conditions and processes influence and constrain our ability to understand MRV, including:**
    - Interannual and geographic variation of influential natural processes
    - Changing baseline conditions
    - Organic carbon export
    - Natural iron cycle
    - Nutrient cycling (near- and far-field)

- **What comparative data from other mCDR and CDR pathways are needed to enable adequate future comparison of pathway specific impacts and costs?**

- **What existing data, new field trial data, observational capacity and model advances are needed to build robust and trustworthy MRV that can evaluate durability of PCS, including use of:**
    - Artificial Intelligence and Machine Learning
    - Existing archived data
    - New field data from natural analogs and/or field trials

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MRV: Next Steps

- **Identify PCS pathways and refine oceanographic regions to prioritize** for integration in the R&D program and identify the priority unknowns for evaluating durability. Tentatively to include:
  - **North Atlantic** OIF field trial under development by ExOIS for proof-of-concept
  - **Tropical Pacific** targeted for iron fertilization for nitrogen fixation
  - **Southern Ocean** improving understanding of observation and modeling needs to inform future scaled opportunities for OIF

- **Workshop: Identify and prioritize the key sources of uncertainty and no-go criteria for MRV & durability** and develop right-sized catalytic research activities to reduce priority uncertainties in 5 years. Tentatively, processes include:
  - Organic carbon export
  - Natural iron cycle
  - Nutrient cycling (near- and far-field)

- **Workshop: Identify and prioritize the activities required to improve model-based MRV capabilities of MRV** for field trials and PCS deployment at scale. Seek opportunities that do not require new data or field trials.

- **Develop a strategy to leverage existing research activities**

Ongoing efforts related to MRV?

Ocean Biogeochemistry Virtual Institute (OBVI). Aims to refine controls on ocean carbon cycling and ecosystem resilience

Bio-Carbon UK. Modeling key processes in carbon flux, ocean carbon storage, and biological pump

GEOTRACES
Modeling impact of iron fertilization on phytoplankton growth and carbon sequestration

Among others…

Controls over Ocean Mesopelagic Interior Carbon Storage (COMICS).
Aim to quantify the flow of carbon in the ocean's 'twilight' zone.

EXPORTS
Aim to quantify the flow of carbon in the ocean's 'twilight' zone

[c]worthy. Building software that supports multi-scale oceanographic modeling and data integration for quantifying the efficacy and ecological impacts of ocean-based CDR

ExOIS. Aims to resolve the impact of enhanced iron fertilization on marine ecosystems and its potential for removal of atmospheric carbon dioxide.

SOLAS. Aims to understand the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere

BioGeoSCAPES. improve our understanding of the microbial biogeochemistry of the oceans from regional to ocean basin-scale on a changing planet

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Environmental Impacts: Goals and Objectives

Five Year Goal: Knowledge on environmental and socio-economic benefits and risks has advanced sufficiently to frame risk / benefit decision-making on PCS.

Objectives:

- Understand **baseline ecosystem conditions** across key indicators of environmental and socioeconomic health to support assessment for field trials and broader impacts.
- Define **expected and acceptable environmental impacts** and their duration and range for key environmental health measures including DO, nutrient depletion and availability, system productivity, and changes in phytoplankton species diversity, both at study sites and downstream.
- Set and articulate quantifiable and acceptable field trial **environmental performance standards** for field trial study sites. Establish monitoring and performance standards with off-ramps based on performance measurement.
- Characterize limits of disruption, containment and reversibility risk conditions for field trials.
- Improve specific ability to understand, predict and monitor fisheries impacts at local and regional scales and incorporate fisheries performance standards into field trial permit conditions.

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Environmental Impacts: R&D Questions

- How do we better understand and incorporate environmental learnings from historical field trials, natural analogs and related studies of system components?

- Do we have sufficient understanding of natural biological conditions, trends and feedback dynamics, from microscopic to ecosystem scales, to confidently predict and assess impact of interventions? What priority actions are required to improve confidence?

- What are current biological modeling capacities? What opportunities exist to integrate biological modeling and geochemical modeling to better predict potential impacts? What improvements to modeling techniques and capacities have the greatest potential to improve our understanding? What are the implications for model use at both localized and regional or global contexts?

- How do we predict and assess fisheries impacts? What additional tools and methodologies could be employed?

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Environmental Impacts: Phase 3 Plan

Draft R&D Program Priorities:

- Workshop(s) on model integration and development to understand natural baseline conditions and implications of interventions at various scales and under different ocean conditions, integration of biological and geochemical models at various scales, deepening of understanding of model capacities, including implications of AI based improvements.

- Commission an investigation to identify the types of and arrays of observational tools to measure environmental impact from PCS , particularly in target field trial locations. What emerging technologies or methodologies hold the most promise?

- Develop terms of reference, targeted convenings, and targeted investment in selected current research initiatives to accelerate advances to better frame longer range R&D questions. Scope and more fully develop performance parameters for fisheries and other biological indicators and mechanisms to both predict and measure observed impacts.

Ongoing efforts related to Environmental Impacts?

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PCS Pathways & Innovations: Goals and Objectives

Five Year Goal: The range of PCS pathways has been explored and the highest potential PCS pathways are defined.

Objectives:

- Identify the **range of novel PCS pathways** under development. Assess and implement evaluation criteria to be used to identify the pathways with greatest promise and need for follow up investment.
- Complete standardized **objective quantifiable assessment criteria** against which to measure cost/benefit of various PCS and mCDR interventions. These criteria should include cost, scalability, environmental risk, and social impacts.
- Prioritize **fit-for-purpose PCS stimulants** to use in areas of highest atmospheric CO2 removal and sequestration potential. Build on and scale research through lab tests and possible mesocosm studies to develop methods to be utilized in field trials and scaled projects.
- Advance **new observational technologies and methodologies** to address key MRV and environmental assessment needs.
- Identify **realistic deployment scales** to define scalability (Gt/yr).

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PCS Pathways & Innovations: Key Questions

- **Which PCS can be prioritized to best achieve sufficient durability and scalability? Are there different answers in different regions?**
- **How do risks and limitations of viability differ across specific PCS?** How do we invest in MRV and environmental impact research for high potential PCS pathways?
- **What pathway-specific improvements in observation technologies and modeling could better enable effective assessment of PCS pathways?**
- **What specific developments or advances in Artificial Intelligence can improve modeling, observational capacities or their integration to accelerate and increase accuracy or precision in MRV and environmental impacts?**

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PCS Pathways & Innovations: Phase 3 Plan

- **Identify the range of PCS pathways (what should be in scope?) and for existing PCS efforts**:
  - Understand relevant underlying technological and methodological innovations.
  - Identify their respective R&D aims, methods, funding prospects, key impediments and timelines.

- **Identify the current funding models.** Gain insights from stakeholders, governance authorities and philanthropic funders about investment criteria. Assess implications of different funding models for PCS pathways and other innovations.

- **Recommend criteria and processes for evaluation of future investments.** Build a proposed framework for future investment decisions. Include core MRV, environmental risk / benefit and cost parameters. Identify conditions and criteria and a possible framework for a voluntary standard setting and clearinghouse available to government and funding interests.

- **Pathway cross-cutting:** Survey the range of modeling, observational and AI tools currently in use to deliver MRV and environmental impact outcomes for PCS. Identify effective ways to prioritize and invest in novel approaches to deliver MRV and environmental impact outcomes.

Select PCS pathways and ongoing efforts?

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Inclusive Decision-making: Goals and Objectives

Five Year Goal: Transparent, inclusive and equitable decision-making criteria and effective mechanisms exist to make decisions on PCS R&D at national and global scales.

Objectives:

- By the end of five years, reach **agreement on critical threshold knowledge** in durability, measurability, scalability and safety. Concurrently, build consensus on stage-gates or off ramps that would define points at which continuing to pursue PCS pathways might no longer be warranted.

- **Standardized program performance parameters** are in place against which to measure field trial performance and impact in areas of MRV, environmental health, economics and social justice.

- **Co-design R&D with rightsholders and local expertise**, and ensure sufficient guardrails are in place to minimize harmful impacts, and benefits are distributed equitably. Create process transparency, and the public is aware of and engaged in field trials.

- Build **an international R&D effort** with leadership from countries near scalable deployment regions. Enhanced legal and political capacity is in place for multiple countries to safely conduct field trials and develop best practices and roadmaps to scale.

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Inclusive Decision-making: R&D Questions

- **What performance criteria must PCS meet to build support for continued PCS R&D?**
- **For the performance criteria, what indicates a no-go criteria and off-ramp decision points?**
- **How do we establish mechanisms for benchmarking PCS pathways against other mCDR and CDR pathways? How do we define likelihood of success concerning cost efficiency and energy inputs?**
- **How do we ensure that state-level permit decisions for field trials are aligned with broader global safety criteria, ethics, and codes of conduct? How can the international community work to find agreement and capacity to align on field trials?**
- **What processes and standards can be put in place to enhance co-design, inclusion, and equity of PCS science, particularly in field trial implementation?**

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Inclusive Decision-making: Phase 3 Plan

- **Scope processes and best practices to improve community engagement** to inform and implement a co-design practice to understand what the impacts, risks, and benefits are and how decision-making can be inclusive and transparent.

- **Identify and recommend inclusivity opportunities within key countries** early on to build trust, develop shared knowledge, and ensure that capacity is strengthened across the field.

- **Develop a strong communications protocol to build public awareness and ensure transparency** on the risks, rewards, and political development.

Inclusive Decision-making: Existing efforts we can build on?

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Program Nuts & Bolts: Aims

- Develop a cohesive, broadly international and collaborative PCS academic research community.
- Effectively prioritize and manage sequencing of key research questions/activities to achieve ambitious timeline of 5 years.
- Establish operating procedures that build trust and acceptability by incorporating rigorous vetting of research, procedures for inclusive co-design of R&D, broad geographic and disciplinary expertise, and a transparent process for scoping RFPs.
- Implement communications that build awareness, inclusion, transparency, consistency, and trust across actors and affected parties in the PCS space. Have in place methods and structures for information provision, access and exchange. Have in place a clearinghouse for sharing data, methods, findings, and experiences.
- Developed and advocated for effective "stage-gating" of field studies and other initiatives. Include rigorous evaluation of progress, risk and benefits and identification of key "deal-breakers" at key steps. Open access consideration of challenges to be addressed.

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Nuts & Bolts: Potential Program Requirements

- Stage gating strategy to inform decision-making at a five-year check point with off-ramp scenarios for pathways, research priorities and other program activities.
- Rigorous and multi-disciplinary peer-review requirements and processes
- Processes for continuous co-design and evaluation
- International R&D Program engagement
- Capacity to look across mCDR and CDR pathways to inform continued evaluation against cost and performance criteria.

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Nuts & Bolts: Phase 3 Plan

Guiding questions

- What effective program structures exist that could serve as effective analogies for a more effective and integrated PCS pathway-wide approach to decision making and implementation?

- How do we create buy-in for an effective “stage-gating” approach to PCS pathway work? Are there models in other pathways or industries that could serve as useful models?

- How we can build and implement a communications plan that facilitates integrated communications at multiple scales, with both technical and non-technical content, in ways that are transparent, informative, serve the needs of diverse constituencies and support effective, risk-based decision-making? How do we create field-wide buy in to participate in communications efforts?

Example R&D programs to explore re: Program Nuts and Bolts?

Next Steps

Plenary Report Out

- **By table, what one issue stood out in the discussion?**

- **What specific advice would you have for the Project team as we move into phase 3?**

Next Steps: Phases 3 & 4

Phase 3: Feedback & Revision

March – July 2025

- Attend conferences, conduct expert interviews
- Second Draft R&D Program
- Scope & conduct first grantmaking

Phase 4: Final Recommendation

July-August 2025

- Final R&D Program Design
- Public-facing materials

Thank you!

For additional information and follow-up:

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