THE CLIMATE CONUNDRUM

# Carbon Dioxide Removal Technology

## Public Forums and Application to Governance Frameworks

**INTERIM REPORT | MARCH 2026**

THE CLIMATE CONUNDRUM

# Carbon Dioxide Removal (CDR) Technology

## Public Forums and Application to Governance Frameworks

This project is supported in part through a generous grant from the Alfred P. Sloan Foundation (2022-9921) to Arizona State University for applying Participatory Technology Assessment (pTA) methodologies to better understand public perceptions of carbon dioxide removal (CDR) research and development in the US and Canada.

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**All public and expert stakeholder participants**

It was their time and knowledge that made this project possible.

**All forum facilitators**

Who guided respectful, productive dialogue and deliberation.

Additional Project Resources

Consortium for Science, Policy & Outcomes at Arizona State University

UNIVERSITY OF MARYLAND

Museum of Science

UNIVERSITY OF CALGARY

ECAST EXPERT AND CITIZEN ASSESSMENT OF SCIENCE AND TECHNOLOGY

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ChatGPT versions 5.3 and 5.4 were used to shorten and synthesize manually produced texts in summary sections. They were not used in research or analysis.


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# Introduction

# Executive Summary

This project uses participatory technology assessment (pTA) methodology to explore how public opinions can shape emerging governance frameworks for Carbon Dioxide Removal (CDR) technologies. Conducted through a collaboration between Arizona State University, the University of Calgary, the University of Maryland, and the Museum of Science, Boston, the study was supported by funding from the Alfred P. Sloan Foundation and strategic initiative funds from Arizona State University. It combines expert analysis with organized citizen deliberation to understand how the public perceives climate intervention technologies and their governance.

Two citizen forums were held, one in Boston, Massachusetts (2024), and another in Vancouver, British Columbia (2025), drawing a total of 113 participants for a full day of discussion. Participants reviewed background materials, discussed climate mitigation strategies, and examined two representative CDR methods: Direct Air Capture with Carbon Storage (DACCS) and Ocean Alkalinity Enhancement (OAE).

## FOUR KEY FINDINGS EMERGED FROM THE FORUMS

### 1 | Participants favored a portfolio approach to addressing climate change.

Participants repeatedly emphasized that addressing climate change needs multiple strategies. They focused on adaptation measures and emissions reductions, while CDR was mainly viewed as a supplementary tool rather than the main solution.

### 2 | Participants showed cautious openness toward CDR.

While recognizing its potential to help reduce climate change, they also raised serious concerns about uncertainty and unintended consequences. “Unknown effects,” including ecological impacts and long-term system changes, were viewed as the most critical factors when evaluating CDR options.

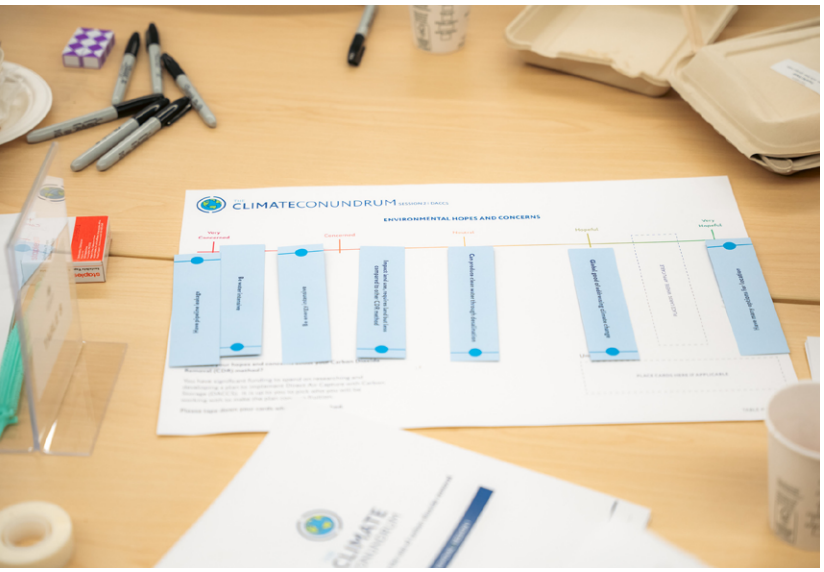
### 3 | Trust in governance institutions is essential.

Participants trusted universities, scientists, and public agencies more to oversee CDR research and deployment. Private companies were consistently seen as the least trusted actors. They emphasized the need for independent oversight, transparency, and robust monitoring and verification at this early stages of CDR research and development.

### 4 | Deliberative engagement increased knowledge but did not significantly change attitudes.

Participants reported significantly greater familiarity with climate change and CDR after the forums. However, their overall opinions on CDR mainly remained the same, indicating that deliberative processes primarily serve as tools for collective learning and informed engagement rather than causing immediate opinion changes.

These findings highlight the importance of participatory approaches in guiding the governance of emerging climate technologies. As CDR shifts from research to potential deployment, incorporating public values into decision-making will be crucial for promoting responsible innovation and maintaining public confidence.




**CDR is framed as both necessary for achieving net-zero targets and uncertain in its ability to deliver at the scale and speed envisioned in climate models.**

# Background

Climate intervention technologies, including terrestrial and marine carbon dioxide removal (CDR), have become a prominent part of contemporary climate policy discourse, yet they are marked by significant epistemic uncertainty.

Pathways assessed by the Intergovernmental Panel on Climate Change (IPCC, 2022) that limit warming to 1.5°C or well below 2°C almost universally rely on substantial CDR to offset residual emissions from hard-to-abate sectors, effectively positioning negative emissions as a "last-mile" strategy after aggressive mitigation and adaptation. At the same time, the IPCC emphasizes that many CDR approaches remain technologically immature and constrained by feasibility considerations, including uncertainties about scalability, storage permanence, land and ocean use trade-offs, ecological impacts, monitoring and verification, and governance capacity. National Academies reports (2022) have similarly called for coordinated research agendas to assess the technical potential, environmental risks, and sustainable scale of terrestrial and coastal CDR approaches, underscoring that deployment decisions require integrated analysis across biophysical and societal dimensions. In short, CDR is framed as both necessary for achieving net-zero targets and uncertain in its ability to deliver at the scale and speed envisioned in climate models.

***Technological development and market construction are scaling rapidly, while the systematic capacity to integrate public values and governance considerations into decision-making remains comparatively underdeveloped.***

Beginning in 2021, public policy in the United States shifted rapidly from research framing to deployment acceleration. The Infrastructure Investment and Jobs Act (2021) and the Inflation Reduction Act (2022) together directed billions of dollars toward CDR research, demonstration, and commercialization, including $3.5 billion for regional direct air capture (DAC) hubs and enhanced Section 45Q tax incentives to improve project economics.

Parallel private and philanthropic initiatives—including advance market commitments, corporate carbon removal purchase coalitions, and large incentive prizes such as the XPRIZE Carbon Removal—sought to create early demand signals and reduce investor risk (Frontier Climate, 2022; XPRIZE 2021). This combined public–private strategy has often been compared to mission-oriented innovation models that blend public risk-sharing with demand guarantees to accelerate technological development. Yet this expansion of engineering and demonstration funding has not been matched by comparable investment in research on ethical, legal, and societal implications (ELSI), public engagement, and governance.

Social science studies documented uneven public awareness of CDR, conditional or variable support, and persistent concerns about justice, equity, and institutional trust (Cox, 2020; Buck 2019). The resulting imbalance suggested a growing knowledge and institutional gap: technological development and market construction are scaling rapidly, while the systematic capacity to integrate public values and governance considerations into decision-making remains comparatively underdeveloped.

## PROJECT PURPOSE AND GOALS

Against this backdrop, in 2022, a team of social science, public engagement, and governance scholars in the United States and Canada proposed a comparative research initiative to examine how geographically and demographically diverse public perspectives on CDR can inform evolving governance frameworks. The project was structured around a three-phase participatory technology assessment (pTA) model developed by the Expert and Citizen Assessment of Science and Technology (ECAST) network, which integrates expert analysis with deliberative public engagement (Kaplan et al., 2021). The original project scope envisioned six deliberative forums—three in each country, selected to reflect distinct political economies—followed by analysis of how results could be integrated into project-level, as well as national and binational level decision-making.

However, anticipated funding for four of the six forums and for the full governance-integration phase did not materialize. The research team therefore convened two forums—one in the United States and one in Canada—and is presenting the findings as interim and exploratory. The results are intended to inform a future research agenda on participatory governance of CDR rather than to serve as direct guidance for current project or policy decisions.

## WHAT IS PARTICIPATORY TECHNOLOGY ASSESSMENT

**Participatory technology assessment (pTA)** comprises structured methods that engage societal actors—affected communities, stakeholders, experts, and members of the broader public—in assessing emerging technologies and their consequences (Grunwald, 2018). At its core, pTA seeks to address democratic deficits in science and technology governance by systematically engaging nonexperts who are typically underrepresented in policy and research decision-making. Unlike organized political, academic, industry, or advocacy actors, lay publics rarely have institutionalized pathways into upstream deliberations about technological development. pTA creates those pathways through carefully designed processes of two-way communication and dialogue that operate across multiple layers of society: from directly affected people and communities to stakeholders and rightsholders to the broader democratic public. This multilayered structure recognizes that technology governance unfolds within nested publics and that legitimate decision-making depends on structured interaction among them.

Building on earlier deliberative models such as the Danish Board of Technology's World Wide Views, the Expert and Citizen Assessment of Science and Technology (ECAST) network developed a three-phase pTA methodology that links problem framing, public deliberation, and results integration (Kaplan et al., 2021). The first phase, problem framing and design, engages subject-matter experts, stakeholders, and community representatives to develop a balanced articulation of the technical and social dimensions of the issue. The second phase convenes diverse members of the public in structured deliberative forums to examine options, trade-offs, and governance considerations related to research and development. The third phase focuses on results integration, in which decision-makers and other intended users interpret the qualitative and quantitative outputs of the forums and incorporate those findings into research planning, policy processes, or institutional practice.

ECAST's approach is explicitly iterative and layered, fostering reciprocal exchange among community members (including those directly impacted), organized stakeholders (e.g., regulators, funders, professionals, and advocates), and the broader public. Federal and philanthropic sponsors have supported ECAST pTA projects for multiple objectives, including informing policy and decision-making on planetary defense, enhancing scientific literacy to build resilience to community climate hazards, mapping public values related to human gene editing, and innovating public engagement processes for nuclear waste siting (Jinnah et al., 2026). In this framework, pTA functions not only as a consultative tool but as a governance mechanism aimed at strengthening the societal capacities needed to steer emerging technologies responsibly.

Following the ECAST pTA model, the project was organized into three sequential phases: problem framing, citizen deliberation, and results integration (see next section).

# Project Phases

The project was organized into three sequential phases.

Phase I. **Problem Framing**

Phase II. **Citizen Deliberation**

Phase III. **Results Integration**

PHASE I

# Problem Framing

Problem Framing established the analytical and normative foundation for the forums. This phase included a **literature review, interviews, open-frame dialogue and forum design workshop** to develop a stakeholder value map of CDR research and development.

## Literature review

The review emphasized a manual search and relevance-sorting of CDR social science and governance literature, yielding insight into existing expert discourse on these topics and gaps in the literature in need of future work.

### KEY FINDINGS

**1 |** Interest in CDR is growing as government, academic, non-profit, and private sector funding and research has scaled up significantly in the last few years.

**2 |** Many open questions remain about the operational characteristics of CDR across the diversity of possible approaches, including their cost, implementation, effectiveness, safety, environmental and economic impact, and more.

**3 |** Research on public perceptions of CDR is limited but indicates mixed perceptions of the technology with greater support for those technologies perceived as more natural.

**4 |** Current governance structures are underdeveloped to handle the complexity of deployment implications and considerations (especially at scale) across local, state, national, and international levels.

## Interviews

This phase also included semi-structured interviews with 15 CDR experts (4 technical experts, 6 social science researchers, and 5 non-government representatives) to identify key areas of convergence and contestation.

### MAJOR TAKEAWAYS

**1 |** Building trusting relationships across sectors is a core challenge for a variety of factors, including divergent priorities and an existing lack of trust/willingness to engage.

**2 |** Deliberation offers a space to build trusting relationships if implemented properly by increasing transparency and responsible research and innovation practices.

**3 |** Community engagement is desirable over public engagement, as CDR projects will be implemented at the community level, in which community members and stakeholders can work through relevant, tangible answers to CDR research, development, and deployment questions.

**4 |** Some participants emphasized that "public engagement isn't just acceptance research,"

**5 |** Others placed significant value on acceptance and social license.

**6 |** It is crucial to engage communities early and often in CDR decision-making.

# Open-frame Dialogue

In parallel, the project team carried out two open-frame dialogues in late spring of 2023; one online with members of the public from the Gulf Coast, and one in person in Boston. 15 people participated in each focus group dialogue for a total of 30 participants. Participant selection for the dialogues emphasized demographic and ideological diversity primarily in terms of gender, race/ethnicity, and age, followed by education, **occupation**, income, political ideology, and perceptions toward energy, the environment, and science & technology.


## PARTICIPANT OCCUPATIONS

### ONLINE: GULF COAST

- Brand Ambassador
- Event Coordinator
- Fundraiser
- Horticulturist Manager
- Not Reported
- Pharmacist
- Project Administrator
- Realtor
- Retired
- Software Engineer
- Student
- Translator
- Unemployed
- Wedding Planner

### IN PERSON: BOSTON

- Accountant
- Brand Ambassador and Scanner
- Building Energy Professional
- Education
- Freelance Multimedia Designer and Producer
- Freelancer
- Health Educator
- Higher Education Administrator
- Not Reported
- Peddler
- Project Coordinator for DEI
- Retired
- Self-Employed Manual Quality Assurance Tester
- Social Worker
- Student

## SESSION AGENDAS

Each open-frame dialogue consisted of **two half-day sessions** designed around the pTA "open-framing" method, which avoids imposing expert framings of CDR on participants and instead opens space for people to generate their own framing of the issue.

### DAY 1

**TASK:** Gather participants' hopes and concerns toward the environment in breakout groups (themed air, land, and water), and have participants generate solutions to their concerns.

### GOALS

- Capture how participants view the current status of the environment and proposed solutions.
- CDR not introduced on the first day so participants do not filter environmental perspectives through the lens of CDR.
- Prompt participants to think in terms of sociotechnical systems.
- Avoid polarization and support constructive, open conversation.

### DAY 2

**TASK:** Gather participants' first impressions of CDR and prompt them to situate CDR relative to other solutions to environmental concerns raised on Day 1.

### GOALS

- Capture participants' sensemaking and framing of CDR.
- Support thinking about CDR as part of broader sociotechnical systems.
- Welcome open, honest, and respectful dialogue about CDR.
- Avoid overlaying expert frames by communicating only the definition of CDR and examples of methods.

## ENVIRONMENTAL CONCERNS

In terms of **environmental concerns**, participants focused on immediate, tangible concerns rather than more abstract concerns like climate change. Their concerns toward the environment can be grouped into the **four broad, sequential categories**, that begins with concerns about unsustainable behaviors and practices. Such practices and behaviors seemingly precedes participants' two most cited concerns–pollution and resource scarcity–as a lack of sustainable behaviors can lead to these negative environmental impacts.These negative impacts manifest in negative effects on the quality and sustainability of life for participants themselves and others including a particular emphasis on future generations and on nature (plants/animals).

### Lack of Sustainable Behaviors & Practices

Participants mentioned a variety of unsustainable behaviors (e.g., overfishing, urban sprawl, excessive water usage, and environmental degradation in general). They also cited unsustainable technology and infrastructure (e.g., water safety emissions from construction, overreliance on personal vehicles).

### Pollution

The most prominent environmental concern. Participants cited air, water, and land pollution (e.g., indoor and outdoor air quality, chemicals in water, and waste management).

### Resource Scarcity

Second most mentioned concern. Participants cited lack of clean air, water availability for humans and animals, lack of green spaces and trees in their environment, and lack of community gardens.

### Negative Effects on the Quality & Sustainability of Life

Participants referred to low pollution, resource scarcity, and other concerns impacting not only themselves but animals, other people, and future generations (e.g., wildlife dying off, pollution affecting health such as asthma and allergies).

## POSSIBLE SOLUTIONS

Participants expressed a variety of **possible solutions** to their environmental concerns; however, they focused on behavioral solutions rather than technological ones.

### Education

Participants cited education and awareness as solutions. Some felt people lack information on environmental issues and that education should address both issues and potential solutions so the next generation feels connected to Earth's future.

### Accountability

Participants emphasized accountability for those in positions of power (governments and private sector) for environmental hazards. Suggested tools included regulations, financial incentives for renewable energy, and incentives to pass environmentally friendly projects.

### Individual & Community Action

Participants noted individuals and communities should adopt sustainable actions (e.g., recycling, creating community gardens, reducing single-use plastics). Community meetings on environmental issues and awareness-building were also suggested.

# Forum Design Workshop

The results from the literature review, interviews, and open-frame dialogues were presented in a **two-day forum design workshop with CDR experts and stakeholders** in October 2023 in Washington, DC and online. The goal of the workshop was to solicit guidance on the design and of the citizen forums. It was attended by experts and stakeholders from the public (National Science Foundation, National Oceanic and Atmospheric Administration, Department of Energy, and Government Accountability Office), private (Vesta Earth, Climate at Stripe, Climeworks and Lynker), academic (Arizona State University, University of Calgary, Oxford University, American University, Columbia university, and UC San Diego), and non-governmental (American Geophysical Union, Carbon 180, Environmental Defense Fund, Resources For the Future, and Kiel Institute) sectors.

## Key findings

### WHOSE PARTICIPATION TO PRIORITIZE?

Workshop attendees emphasized that citizen forums should prioritize individuals and **communities directly affected by CDR research**, demonstration, or deployment. Special attention was given to **vulnerable and historically marginalized groups**, including environmental justice communities, Black, Indigenous, and other communities of color, and tribal and Indigenous nations. Participants highlighted the importance of including **those with local knowledge**, individuals living near proposed or existing CDR project sites, and those whose livelihoods could be affected (e.g., fishing or shipping industries in the context of ocean CDR).

### WHICH STAKEHOLDERS TO ENGAGE?

Workshop discussions identified a broader ecosystem of stakeholders relevant to CDR governance, including NGOs (activist and conservation organizations), CDR developers (startups and companies), funders (venture capital and other investors), researchers (universities and national laboratories), governing actors (local to international), and fossil fuel companies.

### WHERE SHOULD WE HOST THE FORUMS?

Attendees recommended holding citizen forums in CDR host communities, particularly those already engaged in or considering CDR projects. Many of these communities are coastal, reflecting current interest in ocean-based CDR and the siting of direct air capture hubs near coastal infrastructure. The emphasis on host communities underscores a preference for grounding deliberation at the community and project levels, where impacts, risks, and benefits are most tangible.

## WHAT TOPICAL THEMES TO DISCUSS?

- **Intentions and motivations** behind CDR development was a prominent theme. Participants expressed concern that vested interests, especially fossil fuel companies, were shaping CDR trajectories in ways that could undermine broader decarbonization goals.
- **Moral hazard** concerns were raised about CDR diverting attention from emissions reductions. Questions about efficacy were central. Participants identified three dimensions: long-term storage of captured CO2, scalability to levels envisioned in IPCC pathways and cost-effectiveness, including local economic implications.
- **Storage** was highlighted as particularly underexamined relative to carbon capture technologies. Participants also emphasized uncertainties regarding **environmental harms** (ecosystem disruption and cascading effects across geographies and time) and social harms (disproportionate impacts on vulnerable communities).
- **Governance** concerns were widespread. When asked whether current governance structures adequately address stakeholder and public concerns, most participants responded negatively. Existing frameworks were seen as fragmented, voluntary, or insufficient for the emerging scale and complexity of CDR.
- **Additional cross-cutting themes** included the need for rigorous measurement, reporting, and verification (MRV); transparency and accountability; trust-building; and stronger alignment between CDR goals and community values.


## WHAT ARE THE DESIRED OUTCOMES?

Experts articulated several desired outcomes for the citizen forums.

- Forums should **generate usable information** tailored to host communities, starting with identifying what information communities need.
- Fndings should be **shared with decision-makers and stakeholders**, including government agencies and private funders, and integrated into research and funding processes.
- B**roader communication and amplification** through media public meetings, or documentary formats were viewed as important for extending the forums' impact beyond participants.

PHASE II

# Citizen Deliberation

By synthesizing the outcomes of the design workshop with the literature review, expert interview, and focus group results, a day-long citizen forum was designed to achieve (a) informed, (b) inclusive, and (c) facilitated deliberation among 50-60 lay participants representing the demographic diversity of the host location. These goals were realized through the following content.

## Background Information

A 30-page background document was prepared for participants to read before the forum, providing foundational knowledge relevant to the discussion. It included an overview of climate change, actions to mitigate and adapt, an explanation of CDR methodologies and general considerations, and introductions to a terrestrial CDR technology (Direct Air Capture with Carbon Storage - DACCS) and a marine CDR technology (Ocean Alkalinity Enhancement - OAE). An agenda and a list of references for further reading were also provided. The information packet was reviewed by a panel of external experts to assess accuracy, accessibility, and balance.


**Our Background Packet Reviewers**

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American Geophysical Union

Christine Merk,
Institute für Weltwirtschaft, Kiel

Billy Williams,
American Geophysical Union

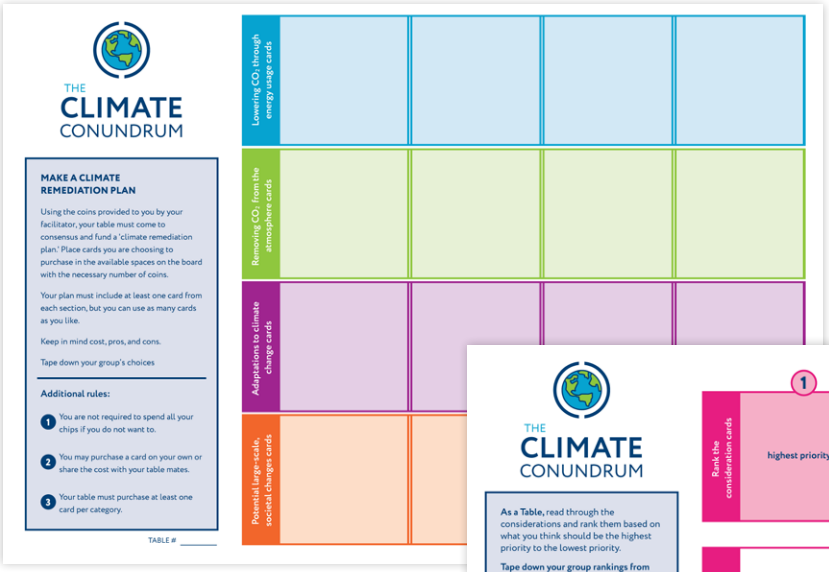
*The finalized background information represents the editorial decisions of the project team and not of our reviewers.

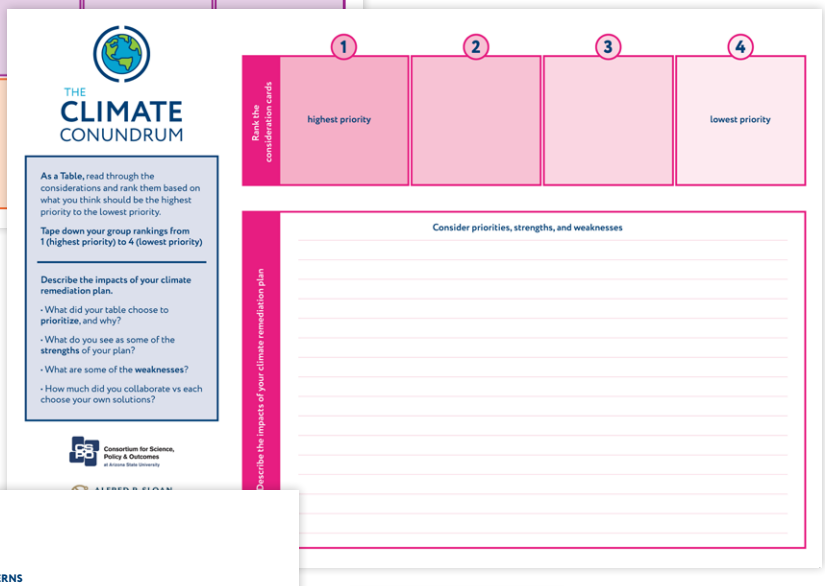
## Informational Videos

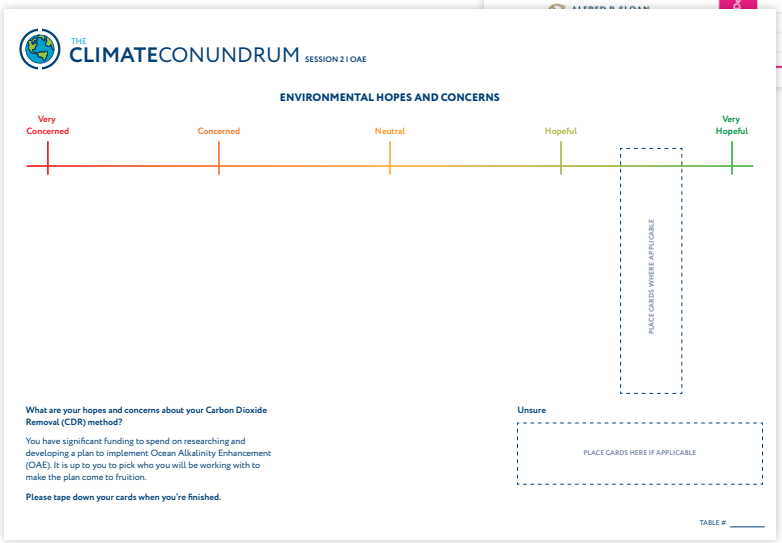
Two videos were prepared to complement the background information packet, recognizing that not all participants would have read it before the forum. The first, 6 minutes long, covered the definition, causes, impacts, and solutions of climate change. The second, 10 minutes long, covered the risks, benefits, and alternatives associated with DACCS and OAE.


# Deliberation Materials

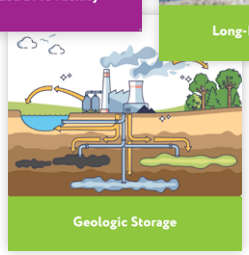
Incorporating best practices and lessons from previous forums, additional materials in the form of workbooks, informational cards, and group activity boards were created to facilitate the discussion as well as collect individual perspectives and group-level priorities and recommendations.





# Facilitation Protocol

A carefully curated agenda was prepared to divide the day into three sessions focused on the these topics:

- **Climate Change Remediation**
- **CDR Case Study**
- **Group Mixer**

The first session focused on **Climate Change Remediation**. It began with an open frame discussion on various climate change solutions inclusive of CDR, followed by a discussion of risk and benefits consideration, and ended with the development and sharing of a climate remediation map. The CDR Case Study session was divided equally among the participants with half of the groups focusing on OAE and the other half on DACCS. Participants learned about each method and shared their hopes and concerns about their respective technology. Then, participants proceeded through a series of steps to learn about and share who they trust to oversee various aspects of CDR decision-making. The day concluded with a Group Mixer session, in which the DACCS and OAE tables shared their CDR plans and identified key similarities and differences between them.

THE CLIMATE CONUNDRUM

A public discussion on the role of carbon dioxide removal

**Agenda – mCDR Group**

*Exact timing is subject to change*

| Sessions | Start | End | Time (min) |
|---|---|---|---|
| Welcome and Introduction | 10:00 a | 10:10 a | 10 |
| Climate Change video | 10:10 a | 10:20 a | 10 |
| **Session 1: Climate Change Remediation** | **10:20 a** | **1:00 p** | **160** |
| Step 0: Table Introductions | 10:20 a | 10:35 a | 15 |
| Step 1: Open Framing | 10:35 a | 11:35 a | 60 |
| CDR Video | 11:35 a | 11:45 a | 10 |
| **Break** | **11:45 a** | **11:55 a** | **10** |
| Step 2: CDR Considerations | 11:55 a | 12:15 p | 20 |
| Step 3: Climate Remediation Plan | 12:15 p | 12:55 p | 30 |
| Share Out | 12:55 p | 1:00 p | 15 |
| **Lunch** | **1:00 p** | **1:55 p** | **55** |
| **Session 2.1: CDR Case Study - mCDR** | **1:55 p** | **3:10 p** | **75** |
| Step 0: Introduction from Lead Facilitator | 1:55 p | 2:00 p | 5 |
| Step 1: Hopes and Concerns | 2:00 p | 2:15 p | 15 |
| Step 2: Research & Development | 2:15 p | 2:25 p | 10 |
| Step 3: Method | 2:25 p | 2:35 p | 10 |
| Step 4: Siting | 2:35 p | 2:45 p | 10 |
| Step 5: Oversight of Development | 2:45 p | 2:55 p | 10 |
| Step 6: Expert Stakeholder | 2:55 p | 3:05 p | 10 |
| Step 7: Summary | 3:05 p | 3:10 p | 5 |
| Share Out | 3:10 p | 3:30 p | 20 |
| **Session 3: Group Mixer!** | **3:30 p** | **3:50 p** | **20** |
| Introduction from Lead Facilitator | 3:30 p | 3:35 p | 5 |
| Step 1: Land and Marine CDR Connections | 3:35 p | 3:50 p | 15 |
| Closing & Evaluation | 3:50 p | 4:00 p | 10 |

**A detailed minute-by-minute facilitation protocol was prepared to guide participants, seated in groups of five to six per table, through the activities in each session.**

# Forum Locations

- **First forum:** Museum of Science in Boston, MA, United States, on Saturday, September 28, 2024,
- **Second forum:** Simon Fraser University's Surrey Campus, located in the Metro Vancouver regional district, BC, Canada, on Saturday, March 29, 2025.

We chose these locations because they are two coastal, metropolitan areas where marine carbon dioxide removal work is moving from a possibility to reality.

# Participant Recruitment

The pTA process was developed to surface the perspectives of those who are often not heard and typically do not have a seat at the table in decisions about emerging technologies. Therefore, we try to have a broad range of ideals, perspectives, and demographics represented in the forum event. For this pTA project, the ASU team partnered with the Museum of Science in Boston and Banyan Consulting in Vancouver, who provided local expertise and advice on the recruitment and selection of participants in their respective locations.

## STEPS FOR RECRUITING FORUM PARTICIPANTS

**1 |** First, the Museum of Science, Boston, Banyan Consulting, and ASU teams circulated an event flyer via listservs, Craigslist, LinkedIn, and other outlets in our networks. This flyer included a link to an application form, in which prospective participants were asked to share their basic demographic information, prior work or involvement in climate change, and views on science and technology. The demographic questions were adjusted between Boston and Vancouver to align with local norms. The application also included informed consent.

**2 |** Once applications were received, the ASU team worked with our local partners to select participants based on local demographic criteria and best practices to ensure diverse groups in terms of ideals, opinions, and experiences. Further, we excluded prospective participants who worked closely on CDR or climate change, as they would be considered 'expert stakeholders' with knowledge and experience that would contribute more appropriately to different parts of the pTA process.

**3 |** Overall, we invited 100 applicants to each forum, and roughly half attended. **Participants receive a $150 USD/$200 CAD Visa gift card to compensate them for the time and knowledge they shared during the forum.** Participants' identifying information was used only for event logistics, as the data were anonymized.


Museum of Science
CENTER for the ENVIRONMENT
The Climate Conundrum
A Public Discussion on the Role of Carbon Dioxide Removal
Saturday, September 28 | 10:00 a.m. – 4:00 p.m.
Museum of Science, Boston
Human activities are causing the Earth's climate to change rapidly. Heat-trapping gases such as carbon dioxide are building up in the atmosphere, causing average global temperatures to increase, contributing to catastrophic issues around the Earth. This event focuses on climate mitigation, or slowing down climate change, through Carbon Dioxide Removal (CDR) technologies. As the science and engineering behind these technologies progress, the social and ethical questions that come along with it must be addressed with public input.
Join us to discuss two emerging carbon dioxide removal technologies: Ocean Alkalinity Enhancement (OAE) and Direct Air Capture with Carbon Storage (DACCS).
Add your voice and apply today to participate in our interactive forum discussion! Applicants who are selected will receive a $150 gift card following the event.
- Limited capacity. Applicants who are selected will be confirmed via email on a rolling basis starting September 18.
- Breakfast and lunch will be provided.
Click Here to Apply
This project is co-presented by the Consortium for Science, Policy and Outcomes at Arizona State University (ASU), the University of Calgary (UC) and the Museum of Science, Boston (MOS), through generous funding provided by the Alfred P. Sloan Foundation. Part of the Museum's Year of the Earthshot, an exploration of the climate solutions and actions we can take now to live sustainably on Earth.
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**Recruitment flyer**

View all of our data

PHASE III

# Preliminary Results

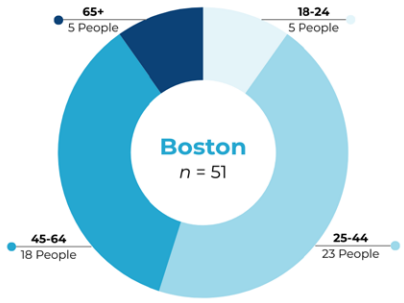
## Who were our participants?

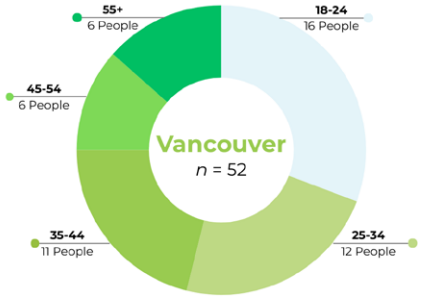
- In total, **113 people participated** in the Boston (*n* = 55) and Vancouver (*n* = 58) forums combined.
- The **majority of Boston participants identified as Democrat, liberal, white, and between 25 and 64 years old**.
- **Boston participants were evenly split between urban and suburban areas**, and were fairly evenly split between identifying as female and male.
- **The majority of Boston participants had a bachelor's degree or higher**.
- In Vancouver, the majority of participants identified as liberal, Chinese or South Asian, and between 18 and 34 years old.
- Most had a bachelor's degree or higher and worked in fields including education, law, social, community and government services, and business, finance, and administration.
- Most participants lived in an urban area and chose not to disclose their political party affiliations. Detailed demographic information is displayed in the charts below
- Overall, the Boston and Vancouver participants were homogeneous in some respects, such as their political leanings and living in coastal metropolitan areas. However, the samples differed in other respects, such as Vancouver participants being younger and more ethnically diverse than those in Boston.

### BOSTON

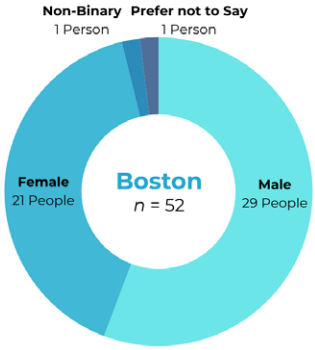
### VANCOUVER

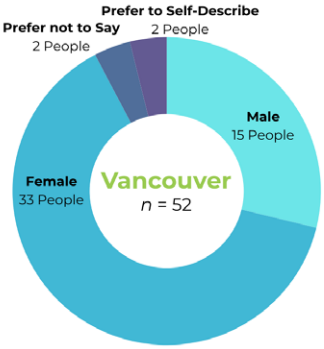
#### AGE




#### GENDER

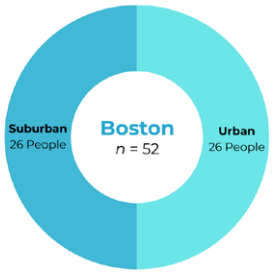


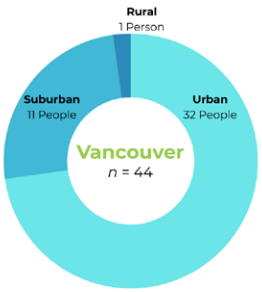



## BOSTON

## VANCOUVER

### GEOGRAPHY



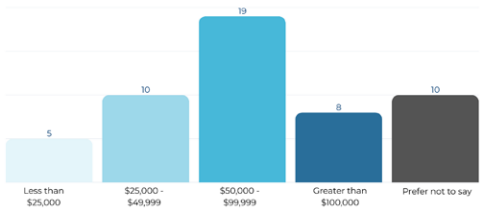

### POLITICAL AFFILIATION



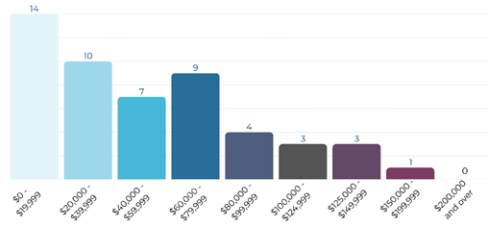
Number of individuals


Number of individuals

### ANNUAL HOUSEHOLD INCOME

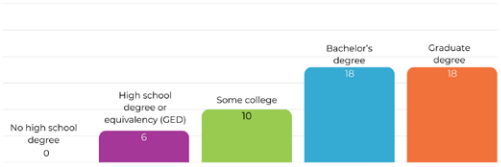



Number of individuals

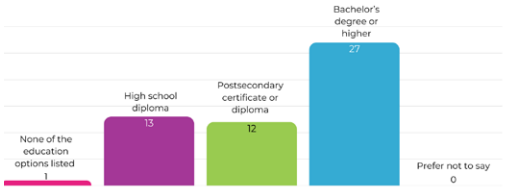



Number of individuals

### HIGHEST LEVEL OF EDUCATION COMPLETED

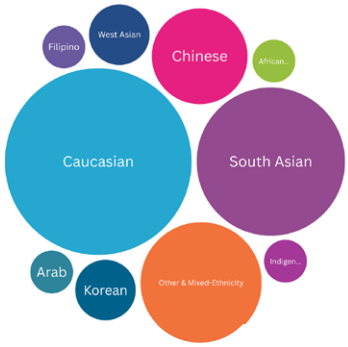


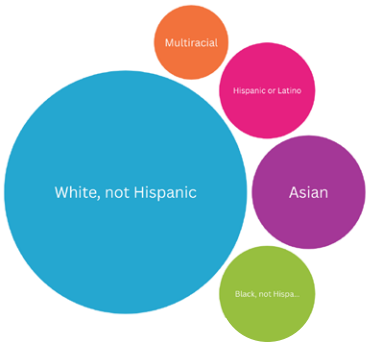

Number of individuals




Number of individuals

### ETHNICITY



## 93% OF PARTICIPANTS IDENTIFIED AS ***ALARMED*** OR ***CONCERNED*** ABOUT CLIMATE CHANGE

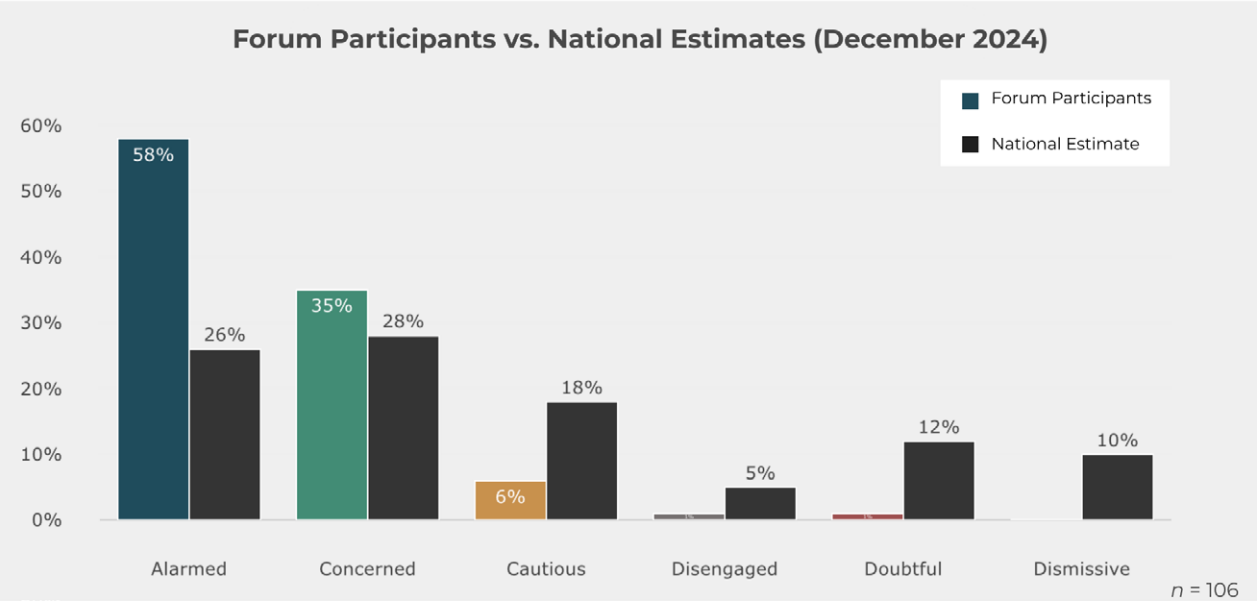
The results of the audience segmentation analysis tell us at least two things.

**1 |** The people in our forums were Alarmed or Concerned about climate change according to the Six Americas Super Short Survey (SASSSY!) Index (Chryst et al., 2026). This means the results our forum produced on climate change solutions and CDR were from the perspective of those who believe that climate change is happening, view it as a serious threat, and that generally support climate policies.

**2 |** Our forum participants do not align with US national estimates.* This means the results of our two forums are missing perspectives on climate change and its solutions from people who are ***Disengaged, Doubtful***, & ***Dismissive.***

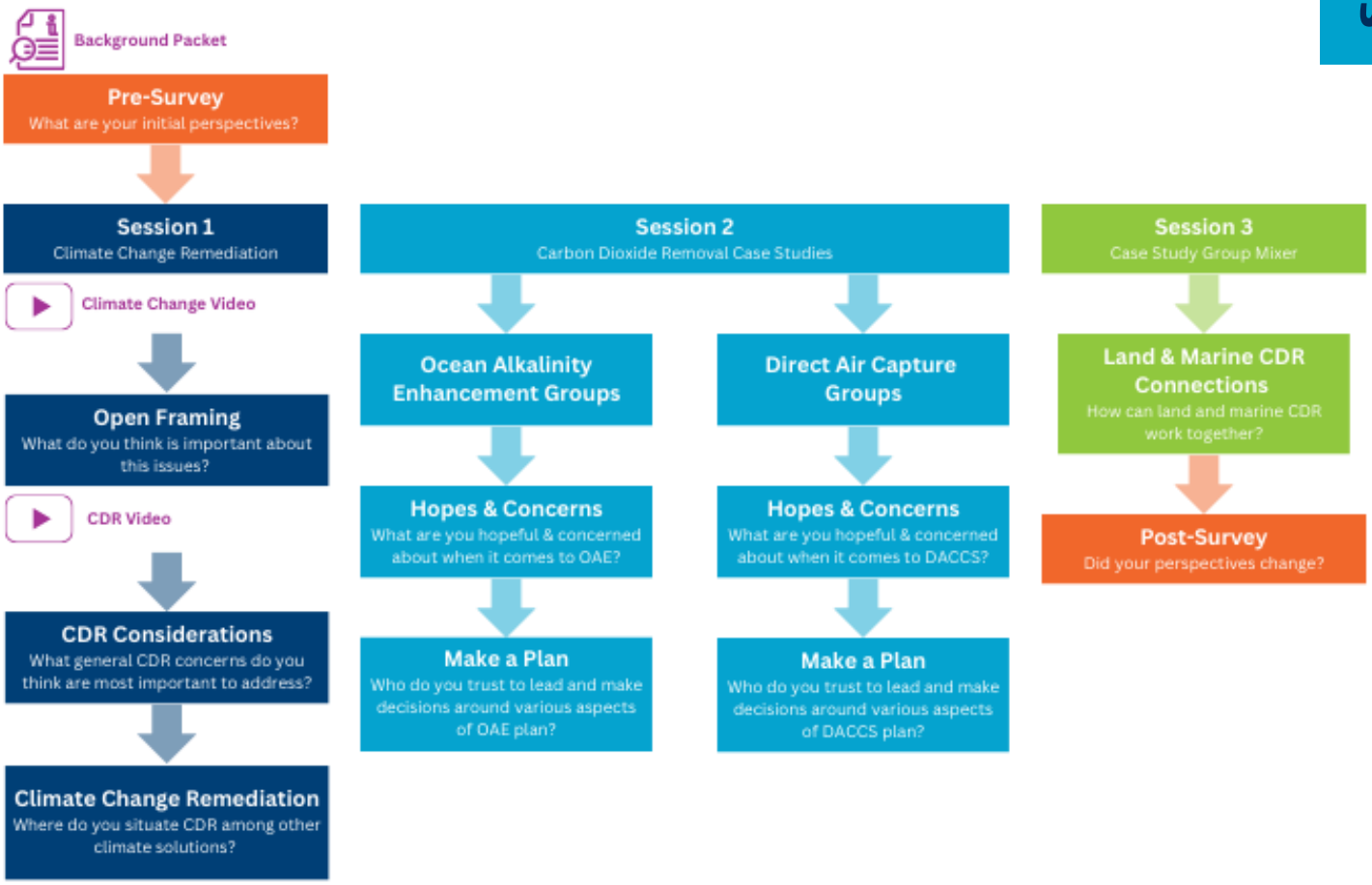
*This prompts the question:*
Should we do more forums to capture these other perspectives?
If so, what is the best way to recruit participants who hold those perspectives?

**Global Warming's *Six Americans Super Short Survey (SASSY!)***



# What was the forum process?

Before attending the forum, participants received an email containing a background information packet (described above), a pre-forum survey, and logistical information. These materials are intended to help participants prepare for the forum by providing information on its topics and structure and offering an opportunity to share their initial perspectives on the forum. On the day of the forum, participants arrived in the morning, had breakfast, and sat at tables in groups of 6 to 7, with a notetaker, and a facilitator who guided participants through different sessions and activities following the facilitation protocol.



# Pre- & Post-Forum Surveys

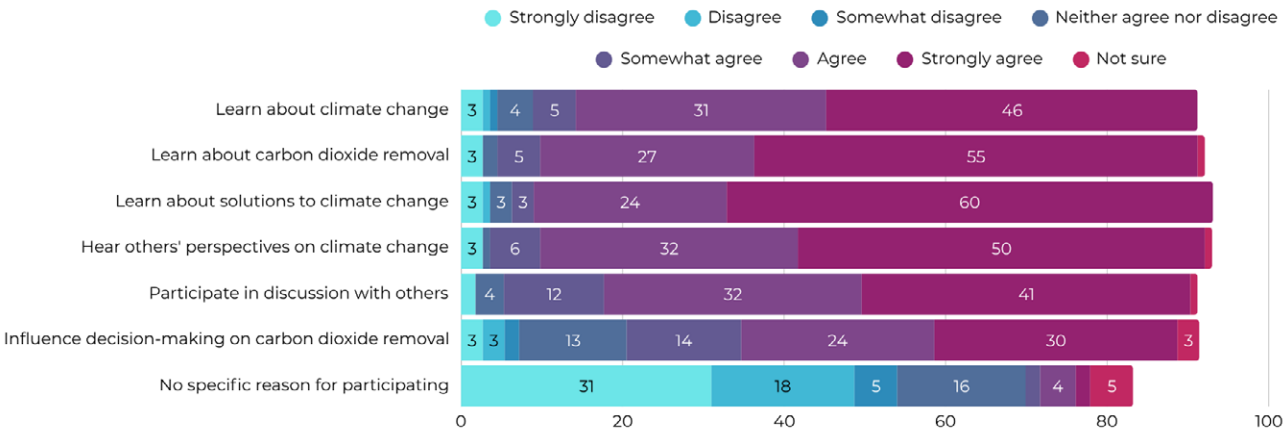
The goal of the pre-forum survey was to gather forum participants' initial perspectives on the forum and its topics, capture detailed demographic information, and measure potential changes in their perspectives relative to their post-survey responses. Therefore, the goal of the post-survey was to capture updated perspectives and feedback on the forum. The pre-survey collected data on participants' motivations for joining the forum, expectations for the discussion, their social and environmental activities, and demographic information. Both surveys included identical questions on participants' beliefs regarding climate change, CDR, science, and public participation in science and technology decision-making. The post-survey included questions about participants' assessment of the dialogue, its results, and the impact of the discussion. Overall, the pre-survey comprised 37 questions, and the post-survey 30. The results in this section represent some of the most relevant findings from the pre- and post-surveys.

## WHY DID PARTICIPANTS CHOOSE TO JOIN THE FORUM?

Participants were particularly motivated to join the forum to learn about climate change and CDR. Over half (53%) of the forum participants strongly agreed that they were interested in participating in the public discussion to learn about solutions to climate change. And, the majority of participants either agreed or strongly agreed that they were interested in participating to learn about climate change (68%), learn about CDR (73%), and hear others' perspectives toward climate change (73%).

**View all of our data**

### Reasons for participating in the forum




**Matrix Question Stem:** How much do you agree or disagree with the following statements? I am interested in participating in this public discussion to...

***N* = 113**

*Data displayed as rounded percentages. Data that do not add to 100% are due to participants choosing not to respond.

## DID PARTICIPANTS' REPORTED KNOWLEDGE AND PERCEPTIONS CHANGE?

We measured participants' reported knowledge and perspectives toward climate change and CDR before and after participating in the forum.

## CLIMATE CHANGE KNOWLEDGE

Regarding climate change knowledge, we asked, "How much do you agree or disagree with the following statements about your knowledge toward climate change? This is not a test! We want your honest answers." The statements included, "I understand what climate change is," "I know the causes of climate change," "I know the impacts of climate change," "I know the solutions to climate change," "I know different people's perspectives on climate change," and others. Participants responded to each statement on a Likert-like scale ranging from 1 = Strongly Disagree to 7 = Strongly Agree (Not sure was considered missing for this analysis).

A paired-sample t-test indicated that participants' reported knowledge of climate change significantly increased in terms of their general understanding of the topic; its causes, impacts, solutions; and other's perspectives toward climate change. Of these factors, participants' knowledge of climate change solutions and others' perspectives toward the topic increased the most after the forum.

## PERCEPTIONS TOWARD CDR ACTIONS

We also asked participants about their perceptions toward a variety of CDR-related actions. The question read, "How much do you agree or disagree with the following statements about activities related to carbon dioxide removal?" The statements included, "Research on CDR is needed to address climate change," "Implementing CDR methods is needed to address climate change," "It is important for CDR decision-makers to understand the public's hopes about CDR," "It is important for CDR decision-makers to understand the public's concerns about CDR," and "It is important for decision-makers to understand the public's ethical considerations about CDR." Response options ranged from 1 = Strongly disagree to 7 = Strongly agree (Not sure was excluded from the paired sample t-test).

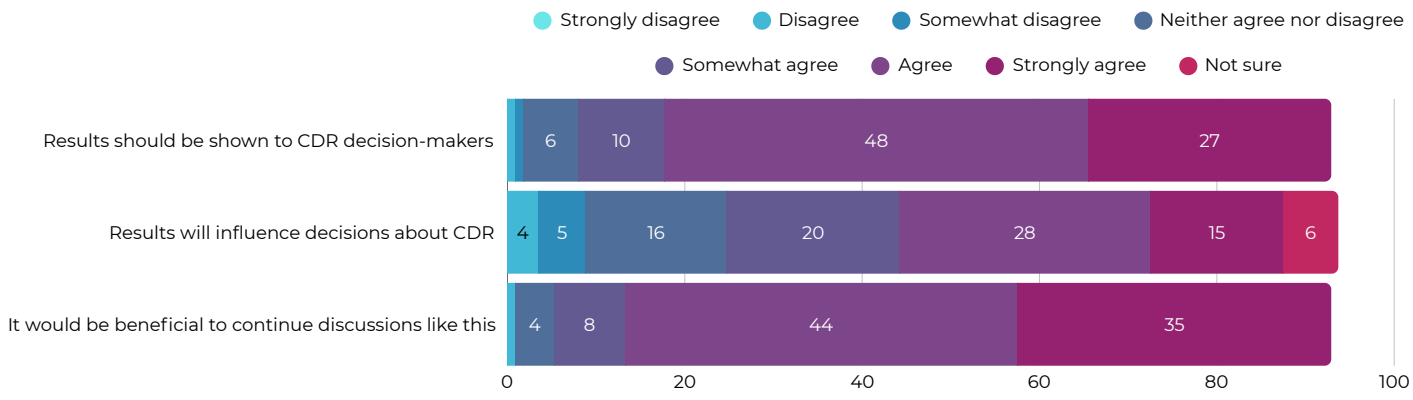
Although participants' mean responses to each statement about CDR-related actions increased during the forum, the change was not statistically significant. Note that the mean responses for each response were already fairly high on the response scale, as the mean responses tended to fall between Agree and Strongly agree.

Overall, participants' knowledge toward and familiarity with climate change and CDR showed a statistically significant increase after the forum, but their views (positive/neutral/negative) toward CDR did not increase significantly.

## EXPECTATIONS FOR FORUM RESULTS

The overwhelming majority of participants either somewhat agreed, agreed, or strongly agreed that the results of these forums should be shown to CDR decision-makers (75%) and that it would be beneficial to continue discussions like this forum (77%). Just over half (56%) of participants thought the results will influence decisions about CDR.

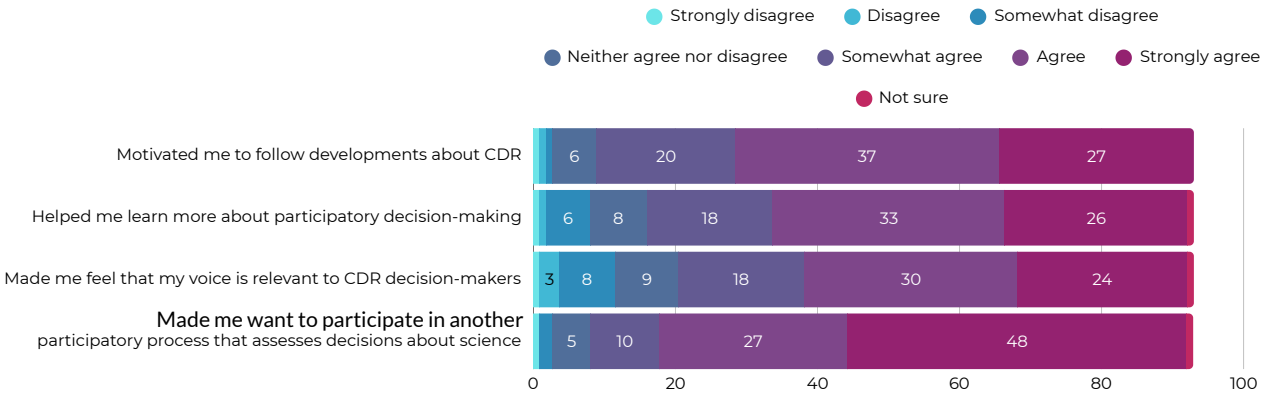
### Participants' Vision for Results



## PERSONAL IMPACT OF THE FORUM

While the forum appears to have impacted participants' motivations and learnings in a variety of ways, the aspect that stands out the most is that nearly half of the participants strongly agreed (42%) that participating in the forum made them want to participate in another participatory process that assesses decisions about science.

### Participants' Perception Toward Personal Impact of Forum Participation




**Matrix Question Stem:** To what extent do you agree or disagree with the following statements? Participating in the discussion...

***N* = 113**

*Data displayed as rounded percentages. Data that do not add to 100% are due to participants choosing not to respond.

## SUMMARY & INTERPRETATION

There are four use cases for participatory technology assessment: **research**, **education**, **decision support**, and **innovation**. The primary use cases for this pTA project are research and education. The educational aspect of the forum stood out in the survey results. Participants were particularly motivated to join the forum to learn about climate change and CDR. There was a statistically significant increase in participants' knowledge of climate change and familiarity with CDR following participation in the forum. However, participants' underlying perceptions of CDR did not change significantly. Finally, participation in the forum motivated most participants to follow CDR's development and to engage in similar discussions in the future. This indicates that this pTA is meeting its intended use case. pTAs are not designed with the purpose to persuade or change people's minds. Rather, they are designed to establish an information base that supports participants in sharing their underlying beliefs, values, and perspectives.

# Forum Results
# Session 1: Climate Change Remediation

The goal of this session was to introduce participants to climate change solutions and CDR, gather hopes and concerns toward those solutions, and understand how participants situate CDR amid other solutions.

## STEP 1
## Open Framing

When discussing a topic, a frame highlights a specific aspect of that issue. This differs from a false 'spin' on a topic; instead, a frame remains true to what is known about the issue (Nisbet, 2010). Often, expert stakeholders set the framing for issues for public discussion. In this activity, we aimed to 'open up' how climate change solutions are framed to understand how the public interprets these solutions with limited influence from expert stakeholder perspectives. In other words, we try to remove expert stakeholder framing from the content so the public can develop their own frames of the topic. Doing so helps us better understand participants' underlying perspectives and values regarding the topic (Nelson et al. 2023; Kaplan et al., 2021; Bellamy & Lezaun, 2015).

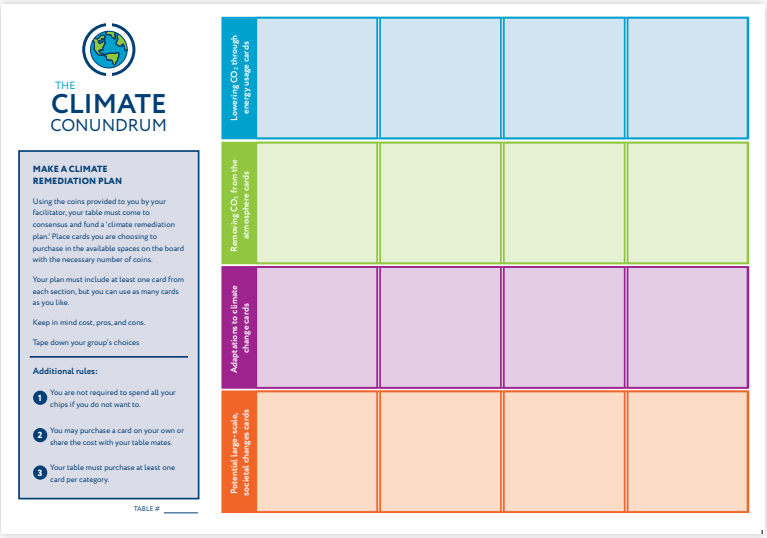
### Participants considered climate change solutions across four solution categories

**1 | Lowering CO2 Through Energy Usage**
Solar Power, Wind Power, Nuclear Power, & Geothermal Energy

**2 | Removing CO2 from the Atmosphere**
Forestation, Ocean Alkalinity Enhancement, Wetland Restoration, & Direct Air Capture

**3 | Adaptations to Climate Change**
Flood Adaptation, Freshwater Access, Heat Adaptation, & Agriculture

**4 | Potential Large-Scale, Societal Changes**
Food Supply Chain, Zoning Laws, Circular Economy, & International Cooperation




In their table groups, participants took turns reading the descriptions of each solution in the category, wrote down their initial impressions of the solutions in their individual workbooks, and worked as a group to share their hopes, concerns, and considerations about each category on an activity board. Overall, this step introduced participants to various climate change solutions, created space for them to share their initial perspectives, and laid a foundation–both of knowledge and personal values–that participants could build on in the following sessions.

## RESULTS

### Lowering CO2 Through Energy Usage

When weighing the many pros and cons of each energy source, groups often expressed that multiple options are necessary. Additionally, the implementation of specific solutions—what to use, where, and how—depends on the geographic and social characteristics of each area (for example, each country should decide what is ideal). In their discussions, groups frequently considered: resource input (such as land use, mining, and infrastructure), intermittency and reliability (for instance, Vancouver does not get much sun), cost (like who can afford renewable energy and how costs vary over time), risks (such as nuclear safety), and waste (including nuclear waste and the recyclability of wind turbines).

*"Each country should consider what energy generation tool is ideal for their relative environment."*
**–Vancouver Participant**

*"Important to balance the right combination of energy generation. Energy storage is important to balance energy intermittency."*
**–Vancouver Participant**

*"Not the whole solution; need to be used in conjunction. Great how they use the Earth's resources but inconsistent."*
**–Vancouver Participant**

*"Could nuclear be used in areas where wind solar and geothermal are not available...Concern about fossil fuels required to manufacture solar technology."*
**–Boston Participant**

### Removing CO2 from the Atmosphere

Groups were cautious about CDR but willing to consider it alongside other climate solutions. They were more open to CDR options they viewed as more natural, such as forestation and wetland restoration.

*"Think these are small pieces that need to be combined as part of a holistic approach to climate. Tailored to local needs and capabilities. Concerned about impact of ocean alkalinity. 'Don't mess with the oceans.' Direct air capture seems like a good idea."*
**–Boston Participant**

*"Worried about risks and long-term impacts. Pilot projects need to test the impact before fully implementing the strategies. More research must be encouraged...Combination of methods to reduce cons and maximize benefits."*
**–Vancouver Participant**

*"Don't put stuff in the ocean that's not supposed to be there. More research needed...Going w/ natural ie. wetland restoration. Plant trees- everyone reward this."*
**–Boston Participant**

## Adaptations to Climate Change

While each group discussed the pros and cons of different adaptation options, they stressed the importance of combining several approaches. Additionally, groups often raised questions about how to implement these methods. Examples of these questions include concerns about uncertainty and the need to better understand zoning laws and their effects; who is responsible for implementing adaptation measures; who benefits and who may be harmed; the cost and affordability of these methods; who bears the financial burden; and the importance of including diverse knowledge in the implementation process (see quotes).

> *"All things (solutions) related to one another –> need to combine solutions."*
> **–Vancouver Participant**

> *"Who accesses these!? They are very broad and how can we guarantee the most people benefit? What is fair & just?"*
> **–Boston Participant**

> *"All groups have their own sets of smarts, and we should respect that + learn from each other."*
> **–Boston Participant**

> *"All could be good. Skeptical about implementation...All seem expensive."*
> **–Boston Participant**

## Potential Large-Scale, Societal Changes

There was little agreement among participants on large-scale societal changes. However, some trends emerged across groups, including the following: There was significant skepticism about the effectiveness of international cooperation. The circular economy was of interest as groups emphasized the need to waste less, reuse more, and create products that last. Some alignment existed across groups regarding the idea that the responsibility to implement change does not lie with individuals but with companies. Groups also considered the systems within which these changes occur and the relationships among those systems.

> *"Difficult to coordinate. Food Supply Chain: Reducing food waste is good–>food waste is bad. Local food/resources. Circular Economy: Also good. International Cooperation: This is a joke/get real! x 4. Zoning Laws: Don't know if these will help. Could be corrupt. Could help but not going to happen."*
> **–Boston Participant**

> *"Top down change is required. The responsibility isn't all on consumer –> opposite!"*
> **–Vancouver Participant**

> *"Waste less, produce less, consume better... Circular economy/int. coop are the most important. Int. cooperation concerns about feasibility and enforcement –>dominant perspectives of global north."*
> **–Vancouver Participant**

## SUMMARY & INTERPRETATION

Three main themes emerged from participants' responses, spanning various solutions for climate change and demonstrating their understanding of a wide range of options.

1 | **Right-Sizing Solutions for Context**: Table groups often consider how different solutions would work across various geographic and cultural settings. They recognize that there is no one-size-fits-all approach to climate change. Instead, solutions should be tailored to meet the physical needs and social preferences of each unique context where they will be implemented.

2 | **A Portfolio Approach:** While participants were encouraged to explore a variety of solutions, table groups emphasized that multiple strategies are needed to address climate change.

3 | **Systems Thinking:** Building on the previous themes, groups frequently adopted a systems approach when discussing climate change solutions. They examined how different solutions interact with each other and fit into the larger systems they could be part of.

Overall, these broad themes were reflected in later forum activities and helped shape participants' perspectives and motivations.

STEP 2

## CDR Considerations

Next, we aimed to help participants think more deeply about the considerations involved in CDR governance, to prepare them for the next round of discussions while collecting their individual perspectives on these considerations.

### Participants delved into the *considerations* that inform decisions about CDR

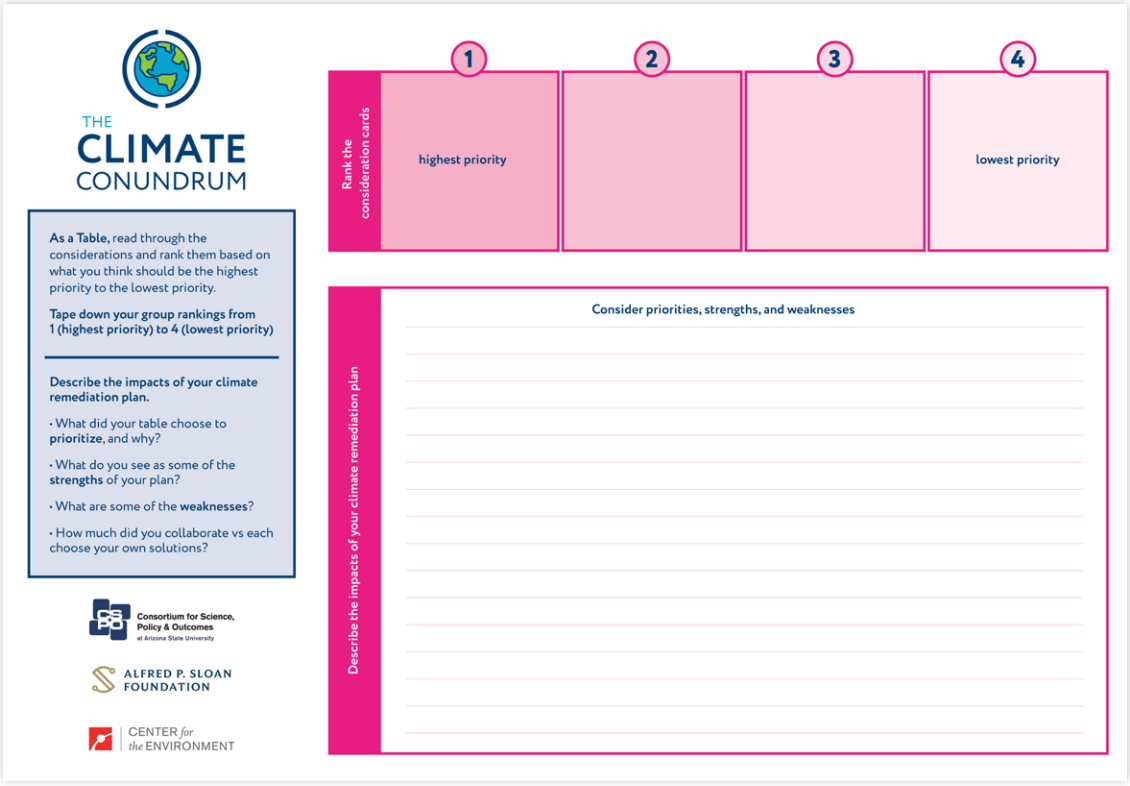
**1 |** After watching the informational video on CDR, participants wrote their initial reactions to CDR in their individual workbooks.

**2 |** In their table groups, participants took turns reading descriptions for four key CDR considerations: upfront investment, carbon economy, unknown effects, and CDR education.

**3 |** Table groups were then tasked with **ranking the four considerations** from highest to lowest priority and providing a rationale for their rankings.

**4 |** Finally, participants were prompted to share their individual rankings and rationales in their workbooks.

## MATERIALS

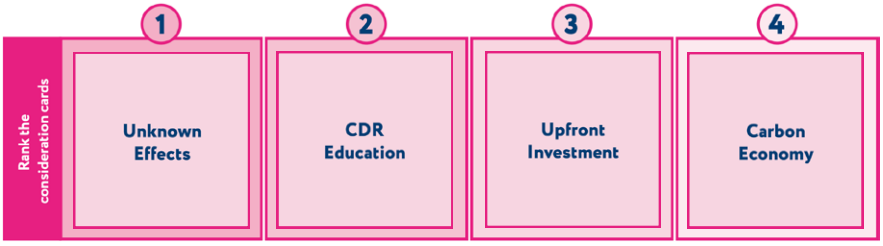


## RESULTS

The consideration rankings were averaged across table groups to establish an overall ranking for each forum location. The table rationales from the Vancouver forum were then examined to identify quotations that reflected the main sentiment or group consideration ranking. Most of the table groups at the Boston forum did not write rationales.

The results of this process showed that participants at the Boston and Vancouver forums ranked the considerations in the same order. Importantly, "Unknown Effects" was overwhelmingly ranked as the top CDR priority, and "CDR Education" and "Upfront Investment" were nearly tied for second and third place among the Boston table groups.

### CDR Consideration Ranking from all groups




### CDR Consideration Rankings: Example Rationales

**1 Unknown Effects**

"...trying to be sure all decisions are made with utmost confidence of their after effects."

"So little resources indicating results. Little research about effects on biosphere."

**3 Upfront Investment**

"Nothing is going to happen without resources."

"Influenced by industry → investments must be long term and strategically."

**2 CDR Education**

"Education - For all policy makers, companies, etc. before decisions made."

"Should be a priority, should be in curriculum, but ineffective if you fail to address peoples' materials concerns..."

**4 Carbon Economy**

"If unprofitable, will only be done through regulation or taxes → should we allow companies to 'buy' their way out of carbon emissions."

"Who does the money benefit...does carbon removal become a capitalistic enterprise?"

## SUMMARY & INTERPRETATION

Overall, unknown effects are the top priority for CDR considerations. This includes not only the impact on ecological and environmental systems but also on global economic and social systems, especially in relation to disparities between developed and developing countries. Table groups believed that decisions about CDR should only be made with high confidence, supported by solid research.

STEP 3

## Climate Change Remediation Plan

The final step in Session 1 combines Steps 1 and 2. Our goal was for participants to utilize their earlier discussions to develop a climate change solutions plan for their group. This helped us understand group priorities when choosing solutions and how different solution categories, especially CDR, compared to each other when resources were limited.

**For this activity, participants worked in their table groups to 'purchase' climate change solutions across the four solution categories to create a climate change plan.**

**1 |** Participants received two chips. Each of the 16 climate change solutions from Step 1 costs anywhere between 1 and 3 chips. The chip cost of each solution was not necessarily representative of real-world costs. Rather, the costs were a relative measure of the technologies compared with one another, as this was an accessible way to prompt participants to choose among solutions. In other words, using chips was more aligned with our purpose and outcome needs for the activity than using real-world costs.

**2 |** We applied three rules to help participants' decision-making: Participants were (1) not required to spend all their chips, (2) could purchase a card on their own or share the cost with their tablemates, and (3) purchase at least one card per category.

**3 |** As a table, groups worked together to deliberate on which solutions to invest in for their plan.

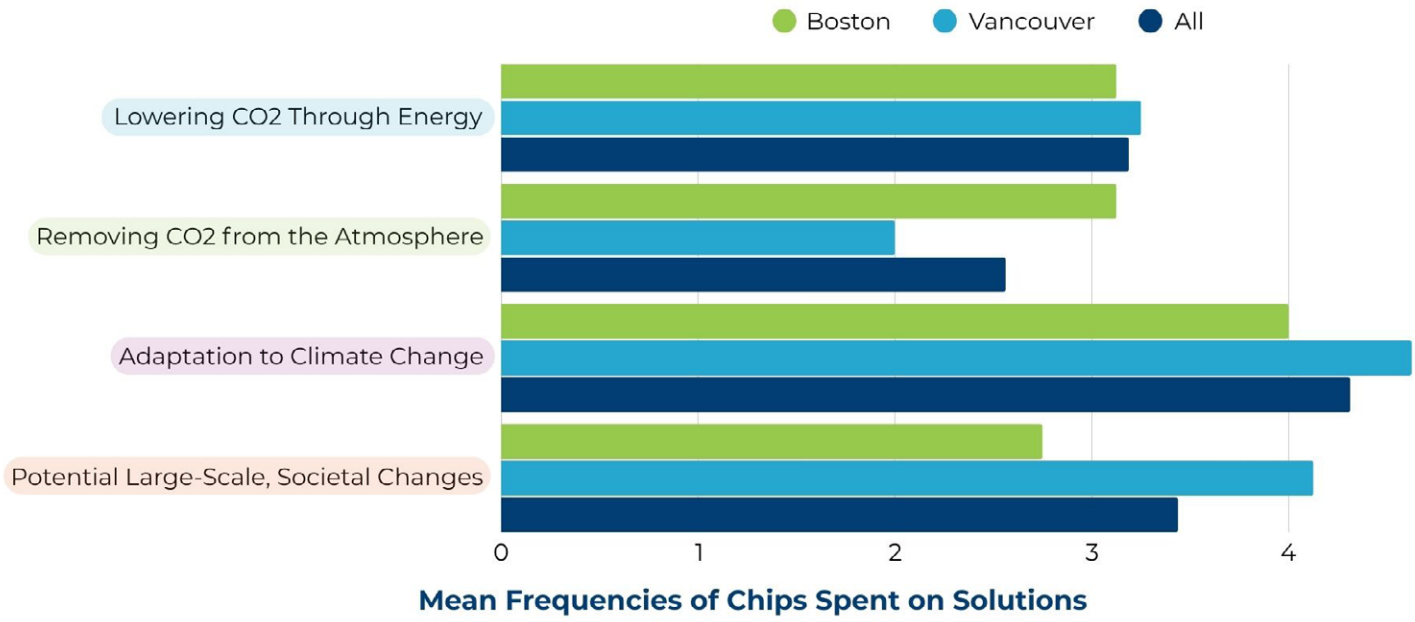
**4 |** Once they developed their plan, they shared their group's rationale for their plan, shared in their workbooks whether the group plan aligned with their individual perspectives, and finally, reported out on their plan to all the forum participants.

## RESULTS

For this step, the amount of chips spent was averaged for each solution category and for each solution across the Boston tables, the Vancouver tables, and both locations combined.

### Across the Solution Categories

Across the four solution categories, ***adaptation to climate change*** received the highest investment from all groups, while CDR received the lowest. Notably, Boston and Vancouver invested similar amounts in emissions reductions but differed in their approaches to CDR and large-scale societal changes. Boston groups invested more in CDR, whereas Vancouver groups allocated more to potential large-scale societal changes.

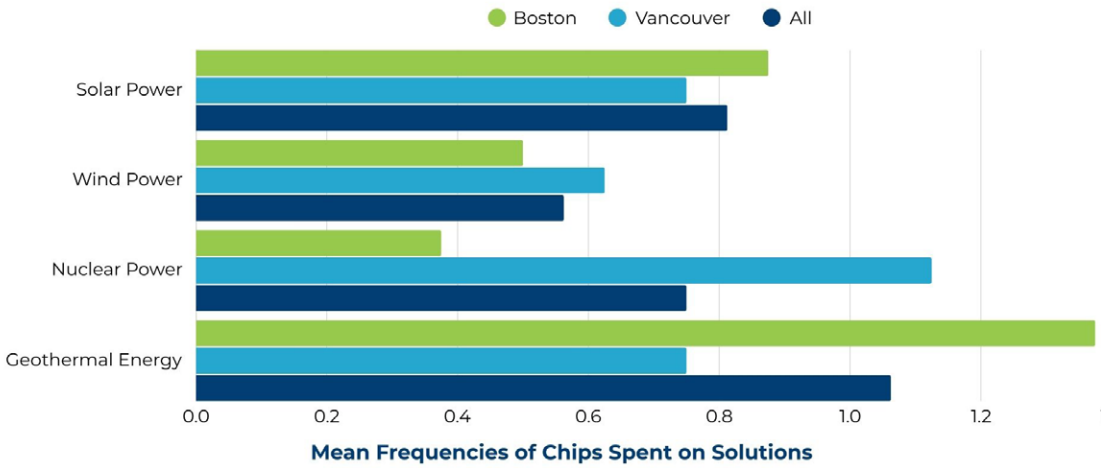



**Mean Frequencies of Chips Spent on Solutions**

## *Lowering CO2 Through Energy Usage*

Both the Boston and Vancouver groups invested similar amounts in reducing CO2 through energy. Boston chose to invest the same amount in reducing CO2 through energy as in CDR. Boston invested more in geothermal, while Vancouver invested more in nuclear energy than in other options.

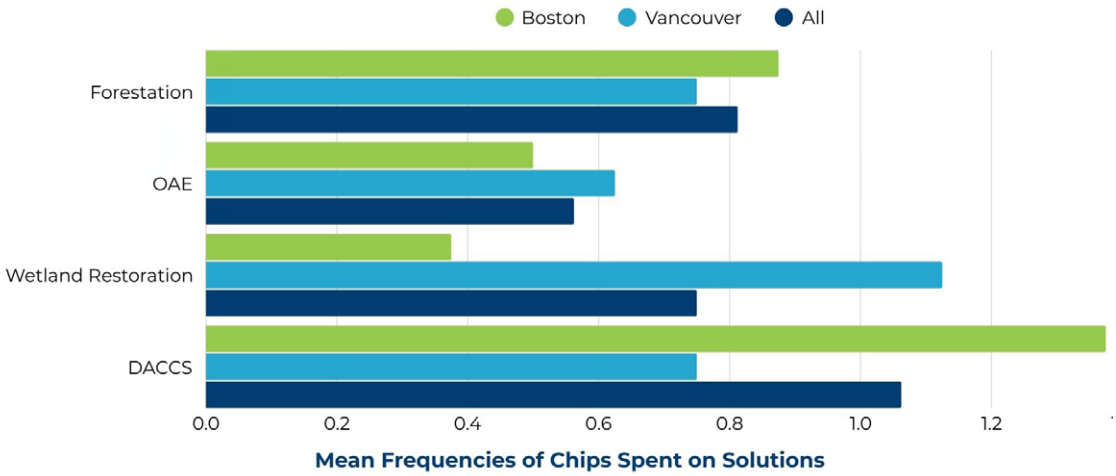
### Group level Results: Lowering CO2 Through Energy Usage




## *Removing CO2 from the Atmosphere*

Overall, groups invested the least in CDR. Boston groups invested more in CDR than Vancouver. Boston invested most in DACCS and Vancouver in wetland restoration. Overall, groups invested the least in OAE.

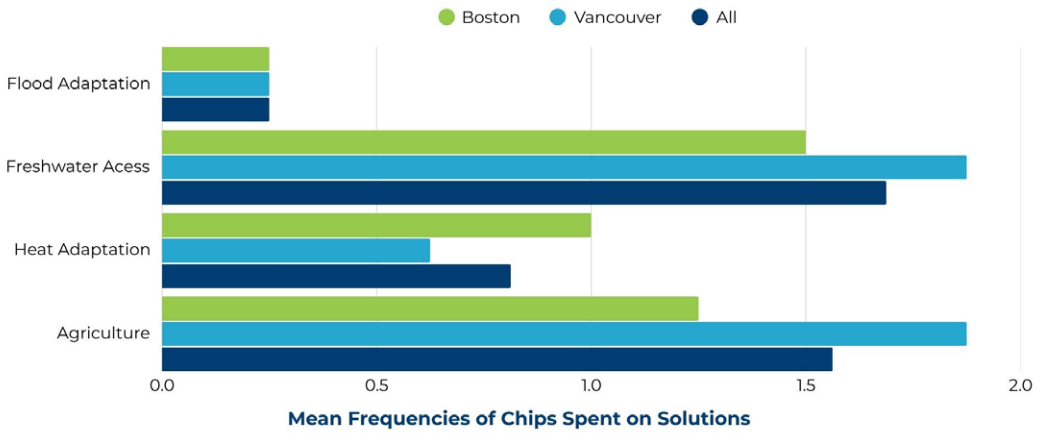
### Group level Results: Removing CO2 from the Atmosphere



## *Adaptation to Climate Change*

Groups in both the Boston and Vancouver forums chose to invest more in climate change adaptation than in other solution categories. Within this category, Boston and Vancouver decided to invest more in agriculture and freshwater access, and less in flood adaptation.

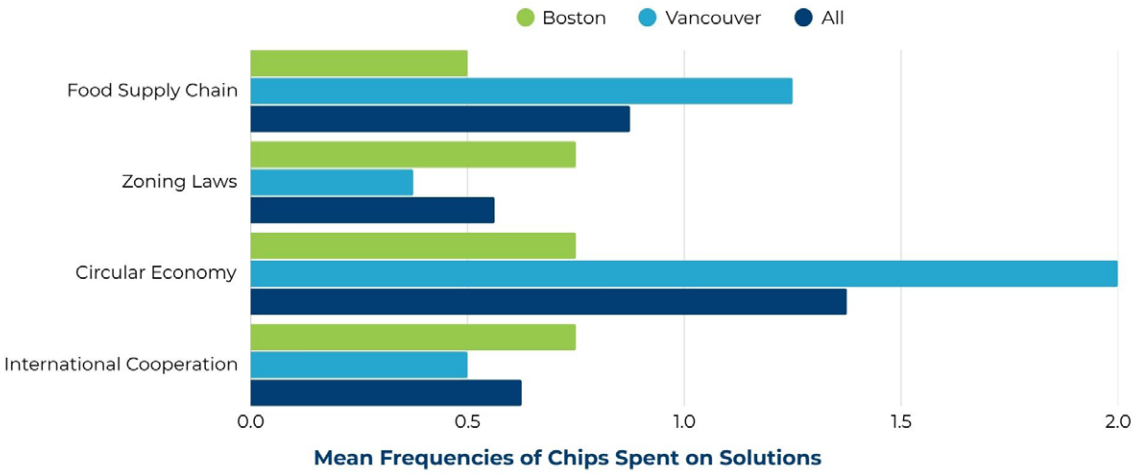
### Group level Results: Adaptation to Climate Change




## *Potential Large-Scale, Societal Changes*

Vancouver invested more in societal changes than Boston. Vancouver invested more in the circular economy and food supply chain than in other options.

### Group level Results:Potential Large-Scale, Societal Changes



# Summary & Interpretation

## Based on Individual Rationales

After analyzing the group-level data from Step 3 quantitatively, the individual workbook data were examined to better understand the reasons behind the group-level results. In their workbooks, participants were prompted to answer the following open-ended question after completing the group activity board:

*Now consider your table group's climate remediation plan. What are your reflections on your table group's plan? Please think about what considerations you personally made when creating a plan with your group and your personal relationship to the plan.*

Participants' responses were inductively coded to identify themes in their rationales for decisions about climate change solutions, both overall and for each individual solution and solution category. The key takeaways from this analysis are as follows.

## KEY TAKEAWAYS

### Portfolio Approach

A key theme that emerged from participants' responses was 'a portfolio approach,' which aligned with the group-level findings from Session 1 Step 1: Open Framing. This was among the most prominent themes from participants' individual rationales and served as a foundational element of their reasoning. Although participants were prompted to consider multiple types of solutions in their climate remediation plan, they frequently referenced the need for multiple solutions in their responses and, in some cases, expressed a desire to include more solutions in their plans.

> *"Our climate plan tackles aspects from every single category. I think that it is important because you can't tackle climate change in one single way. The damage that's been caused by global warming are catastrophic already so we need to take as many steps to help reverse or stop the damage. For example, continued use of wind power is an important part of our efforts to combat global warming."*
> **— Boston Participant**

### Education

Education was also a key theme in participants' rationales. While education was not a deciding factor in their choice of solutions, participants cited it as a key principle guiding decision-making on climate change solutions. Among the participants who mentioned education, it appeared that they saw it as a prerequisite for making effective decisions about climate solutions. Participants also mentioned that education can help gain support for solutions, direct funding and implementation of solutions, and help which solutions to proceed with among a wide suite of options.

> *It is my fear that humans leap before we look. We make decisions without proper information, and/or the motivation to do things financially and therefore make long-term mistakes."*
> **—Boston Participant**

### Environmental Impact

There were two other factors that were prominent in participants' decision-making processes. One is 'environmental impact.' Participants considered the environmental impact of different solutions, as some participants cited protecting and restoring the environment, considering the pros and cons of using available resources, its sustainability, and perceived naturalness.

> *"We considered more relevant aspects such as circular economy as recycling materials will always be prevalent. We mostly focused on more sustainable solutions such as solar power and geothermal energy and natural resources. Nature based and local approaches as opposed to international 'solutions' as local solutions are more easy to be agreed upon conceptually (even though community based solutions need to be green lit by higher authorities but I digress.) We focused on more PREVENTATIVE measures than REACTIVE."*
> **—Vancouver Participant**

### Human Connection

'Human connection' was also a key factor in participants' decision-making. This theme came in a variety of flavors. Participants cited their personal connection, such as knowledge and experience with different solutions, place-based considerations, value for humanity, and the need to change human habits.

> *"I focused more on issues that I have direct connections to, I spent my two tokens on heat adaptation and solar panels. More of a proactive/remediating action in terms of alleviating the current impact with heat and making it so we use less energy to cool spaces down. Solar panels I know are relatively accessible for being built in personal homes/apartments/parking lot garages. Back in California, my family and much of my neighborhood has solar panels and they're super convenient and cheaper. I think we use a mix though or use it to power the emergency generator; not too sure."*
> **—Boston Participant**

Additionally, participants' responses revealed other, less prominent factors that guided their decision-making. These included whether or not solutions address the root cause of climate change, cost, and practicality.

Finally, there were some notable themes that flowed from these overarching themes to support participants' decision-making between solutions and solution categories. Renewables were appealing to participants, in part, because they are ready to implement now. Adaptation options tend to address immediate needs that communities are facing now, such as freshwater access. Large-scale societal changes were included in participants' solution plans; however, there were not enough individual statements about these solutions to confidently draw conclusions about participants' rationales. And finally, regarding CDR, participants showed a strong preference toward forestation and wetland restoration over DACCS and OAE, in part due to the co-benefits for the environment.

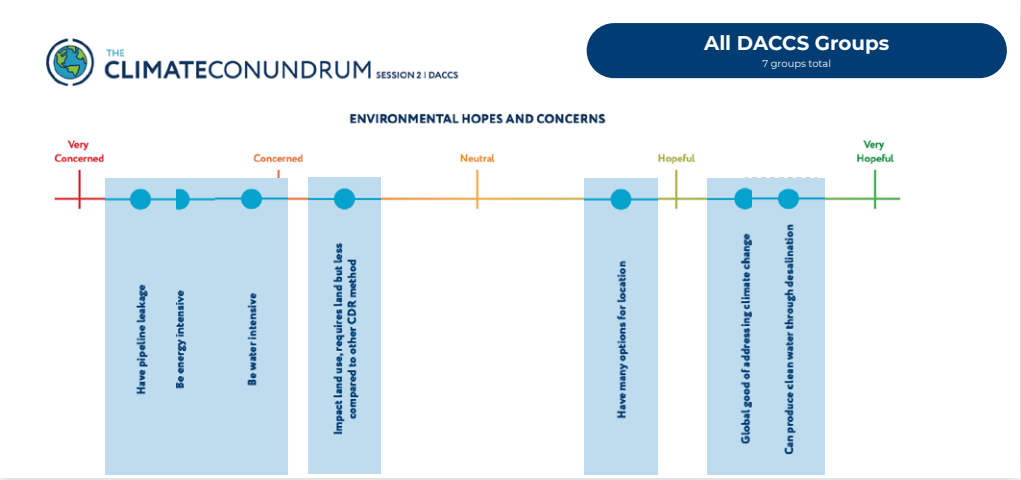
Overall, participants preferred a portfolio approach. Key reasons for their choice included information and education, environmental impacts, and human connections.

# Forum Results
# Session 2: CDR Case Studies

The goal of this session was to learn participants' hopes and concerns toward options, and who they trust to lead various aspects of a hypothetical project. Specifically, we sought to understand these factors in the context of land- and ocean-based CDR methods, so participants' small groups were assigned either *Direct Air Capture with Carbon Capture & Storage* (DACCS) or *Ocean Alkalinity Enhancement* (OAE).

## STEP 1
## Hopes and Concerns

The purpose of this step was to gain participants' initial impressions of their respective CDR methods, DACCS or OAE, while also familiarizing them with the CDR method they would be working with in Steps 2-7: the CDR Plan.




### What they did

**1 |** Participants read a description of their assigned CDR method.

**2 |** They shared their individual hopes and concerns about their assigned method in their participant workbooks.

**3 |** Participants then proceeded with a table group activity. They were provided with a set of common considerations related to their CDR method and tasked as a group with rating these considerations on a scale from very concerned to very hopeful on an activity board. Participants were also provided with blank cards to add their own considerations to the board.

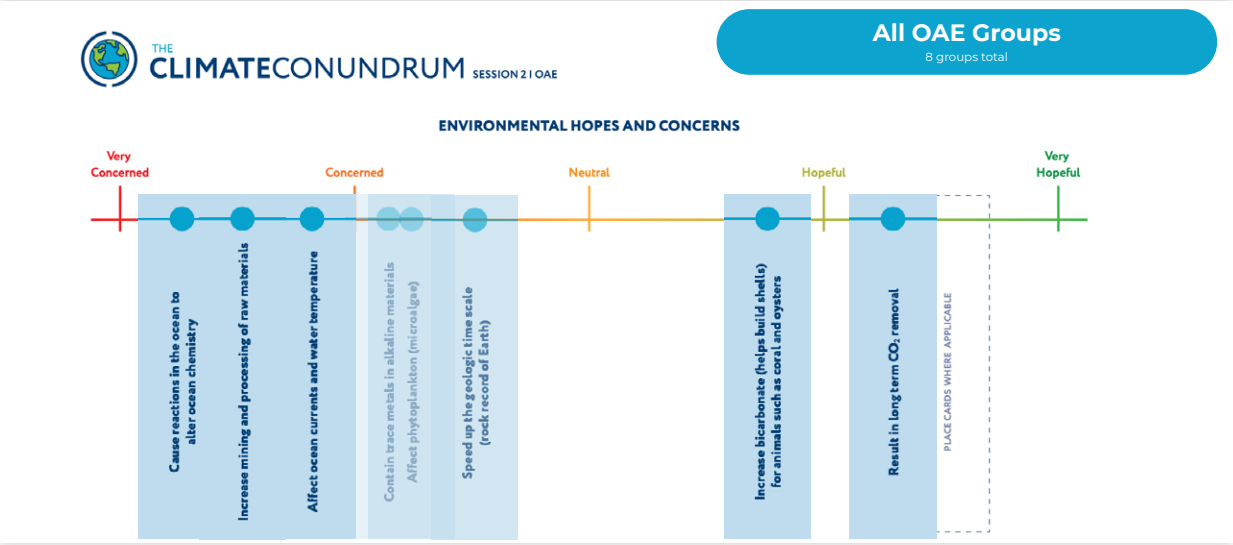
**4 |** Finally, they could choose to add a consideration to an 'undecided' category. Overall, they produced a scale of considerations regarding their assigned CDR method, ranging from *very concerned* to *very hopeful*.

## RESULTS

The considerations from the group activity boards were assigned a number to represent where participants placed them on the scale of 1 = Very Concerned to 5 = Very Hopeful. The values assigned to each consideration were averaged across the Boston groups, Vancouver groups, and all groups to display the final results.

### Key takeaways

- **All groups** were hopeful that OAE and DACCS would result in long-term carbon removal and address climate change, respectively.
- However, types of concerns raised differed between the two technologies. Regarding OAE, 'tampering with nature' was a shared concern among **multiple groups,** reflecting unease about deliberate interventions in the ocean system.
- Regarding DACCS, **all groups** were, to some degree, very concerned about energy demand, infrastructure requirements, safety considerations, and resource use.
- Participants also expressed uncertainty about some considerations, particularly for OAE. **Several groups** placed certain considerations in the "undecided" category, indicating that they felt additional research or information would be necessary before forming an assessment.
- Although Boston and Vancouver groups sometimes differed in the degree to which they rated particular considerations as hopeful or concerning, and there were a few instances of divergence (eg., increase bicarbonates for animals such as corals and oysters for OAE), the **types of concerns associated with each technology were broadly consistent across both locations.**



Additionally, participants chose to write in a variety of considerations, as displayed below.

**Ocean Alkalinity Enhancement**

**Hopes**
- "Require the tones of shells of oysters, lobsters, oysters, etc. by grinding up + duming back in the ocean"
- "Long term solution"
- "Get the community on board"
- "Increase int. cooperation (we all share our oceans)"

**Neutral**
- "Success stories,very small scale testing to be sure of long term effects"

**Unsure**
- "Will change all patterns that relate to the ocean"
- "Net Carbon Impact of the mining"

**Direct Air Capture w/ Carbon Capture & Storage**

**Hopes**
- "Potential to integrate with other stuff"

**Neutral**
- "life of the infrastructure, culture, effectiveness, maintenance"
- "Efficacy of the method"

**Concerns**
- "might lead to tech-solutionism :("
- "Storage integrity"
- "Unknown long-term real effects of carbon storage & transportation"
- "Waste? CO2 created/energy consumption"
- "Whose lands are being used?"
- "Who is funding this?"
- "Transportation (+ more energy use)"
- "Discontinue other methods of CDR"

## SUMMARY & INTERPRETATION

The Hopes and Concerns exercise revealed several consistent patterns in how participants evaluated carbon removal technologies.

- Participants often assessed the technologies in relation to environmental systems and broader societal impacts, rather than focusing solely on the amount of carbon dioxide that could be removed. Concerns about ecological consequences, resource use, and technological uncertainty appeared frequently across both forums.
- However, the nature of these concerns differed between the two technologies.
- For OAE, participants most frequently raised concerns about marine ecosystem impacts and uncertainty about altering ocean chemistry. These concerns reflected the perception that OAE involves direct intervention in complex environmental systems.
- For DACCS, concerns more often centered on energy demand, infrastructure scale, and economic feasibility. Participants frequently described DACCS as an industrial system whose impacts depend on energy sources, facility construction, and operational costs.
- Despite these concerns, participants across both locations expressed hope that carbon removal technologies could contribute to addressing climate change. Participants often described these technologies as potential components of a broader portfolio of climate solutions rather than standalone strategies.

## STEPS 2-7
# CDR Plan

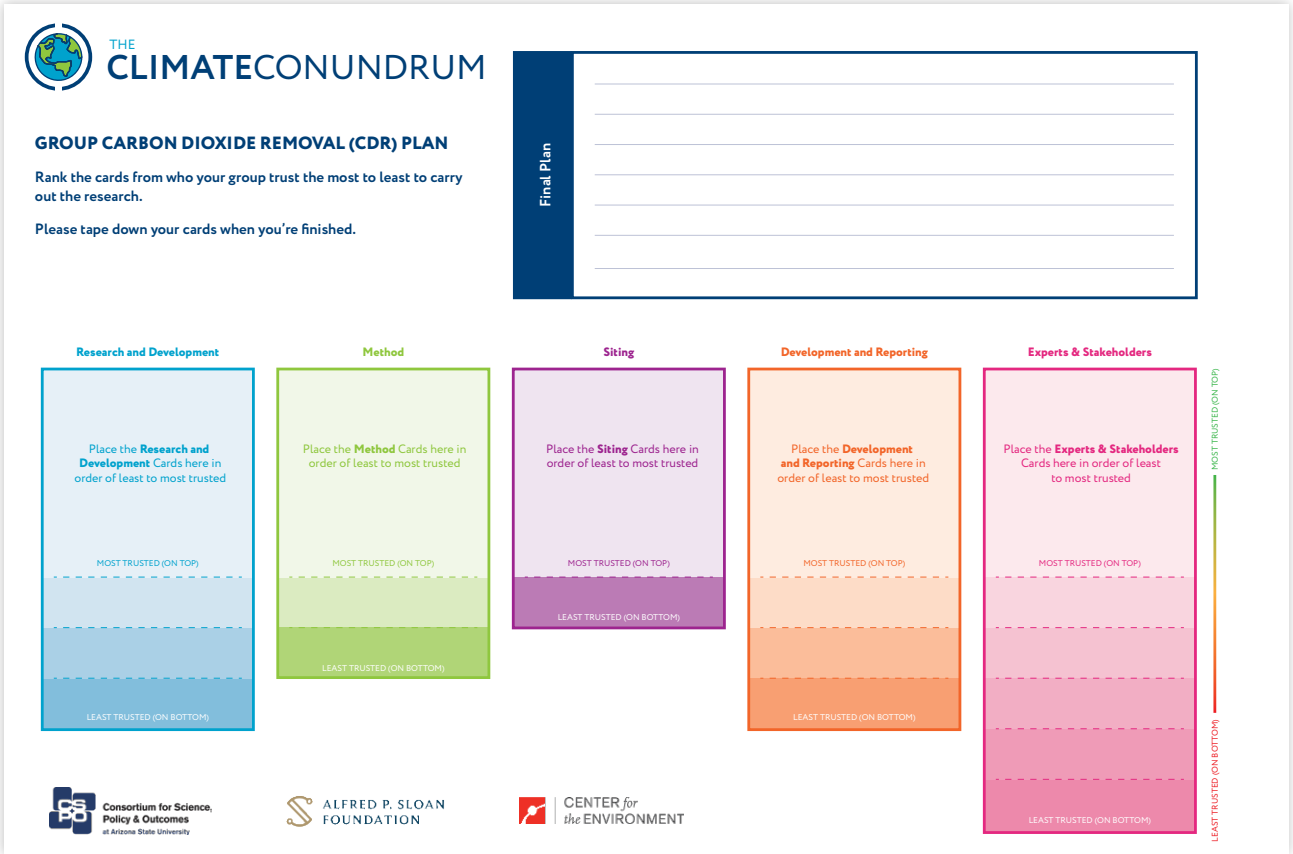
Having established a solid foundation of hopes, concerns, perspectives, and values regarding climate change solutions, including CDR, participants were asked to build on this knowledge by sharing who they trust to oversee different aspects of CDR. This allows us to understand what factors might influence trusted governance of these technologies.

### What they did

**1 |** For each major component of a CDR project, table groups started by reading from a set of cards that offered options for governing each major component.

**2 |** They then worked together as a group to rank the cards from most to least trusted for governing that particular component of the project. Note that Research & Development was included for the OAE groups since this method is in a lower level of technological readiness than DACCS.

**3 |** Once all rankings were complete, table groups wrote a rationale for their decisions and wrote individual reflections in their workbooks.



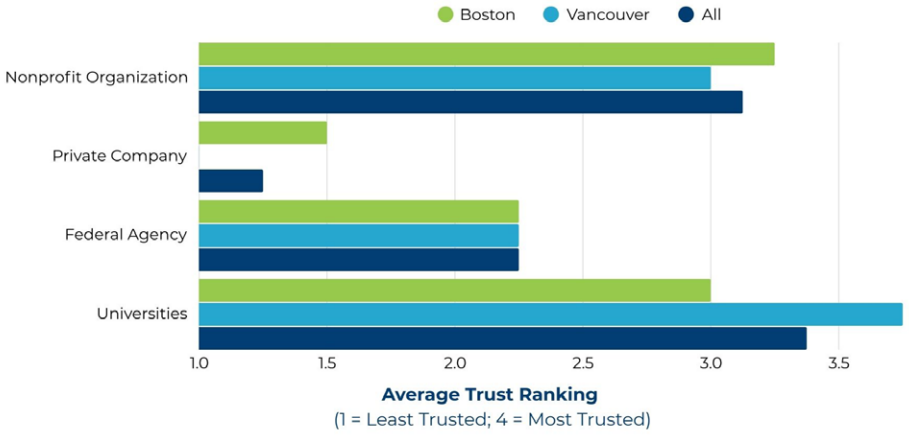
## OAE RESULTS

The group-level CDR plans were analyzed for this report. Ranks were tallied and averaged to produce results for Boston, Vancouver, and the combined locations.

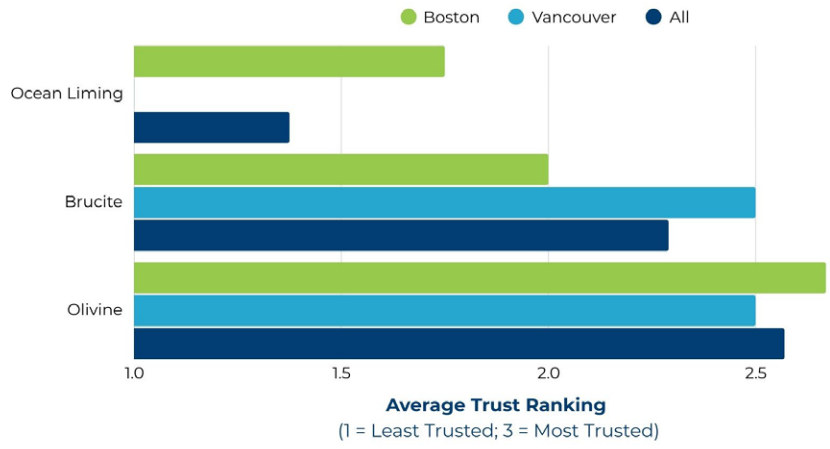
### The most trusted across groups (OAE)

- Research & Development: Universities
- Method: Olivine
- Siting: National Waters
- Oversight & Development: Federal Agency
- Expert Stakeholders: Indigenous Tribes, Nations, & Communities

### OAE: Research & Development




### OAE: Method




### Example OEA Rationales

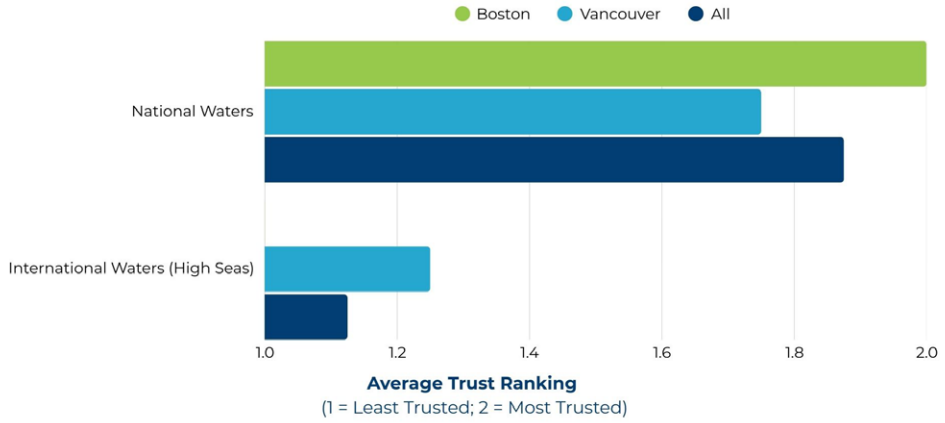
*"The focus was transparency and accountability (transparency, agenda, & responsibility. Control was also a consideration in regards to siting. The least environmental impact was the rationale with the determination of process, Olivine, although liming would double the impact. Advisors must include Indigenous Tribes as original stewards of the land and water."*
**–Boston Participant**

*"We consistently decided these decisions should not be made based on non profit. We prefered universities + scientists for research/advising, and prioritizes appropriate regulations + transparency for siting and reporting. We didn't feel we had sufficient info on the methods, but determined a slight preference for olivine."*
**–Boston Participant**

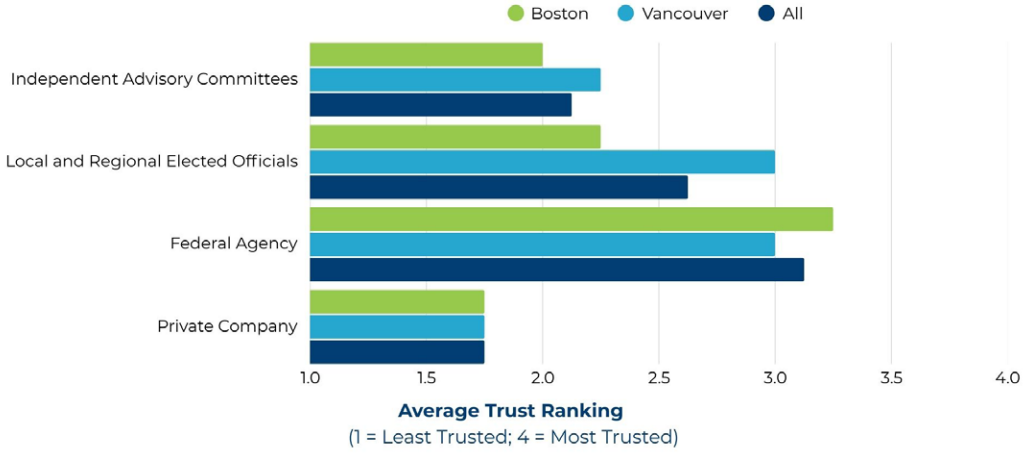
*"Academic freedom/rigour produces better research. Testing should be local/ accountable/equitable. Industry is often faster in implementing new methods. Ind. knowledge is holistic, local, and harmonious w/ natural systems. This group wrote the following terms next to each category: Research and Development: Reliable. Method: Pretty. Siting: Fair. Development and Reporting: Fast. Experts & Stakeholders: Experience."*
**–Vancouver Participant**

*"Prioritizing local + indigenous knowledge in all steps of the process, over opinions like private companies."*
**–Vancouver Participant**

## OAE: Siting




## OAE: Oversight of Development




## OAE: Expert Stakeholders

## DACCS RESULTS

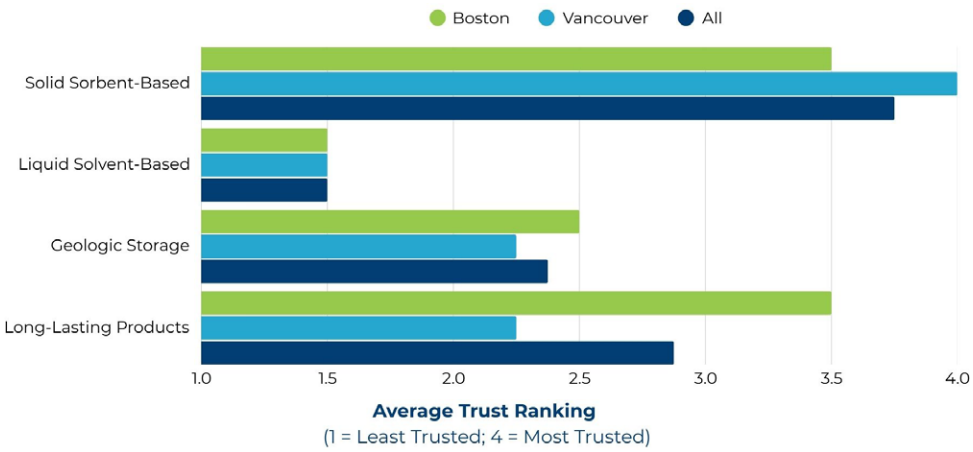
The group-level CDR plans were analyzed for this report. Ranks were tallied and averaged to produce results for Boston, Vancouver, and the combined locations.

### The most trusted across groups DACCS)

- Method: Solid Sorbent-Based and Long-Lasting Products
- Siting: Centralized DAC Facility
- Development & Reporting: Independent Advisory Committee
- Advising: Scientists

*Finally, industry and private companies were the least trusted cross OAE and DACCS groups.*

### DACCS: Methods



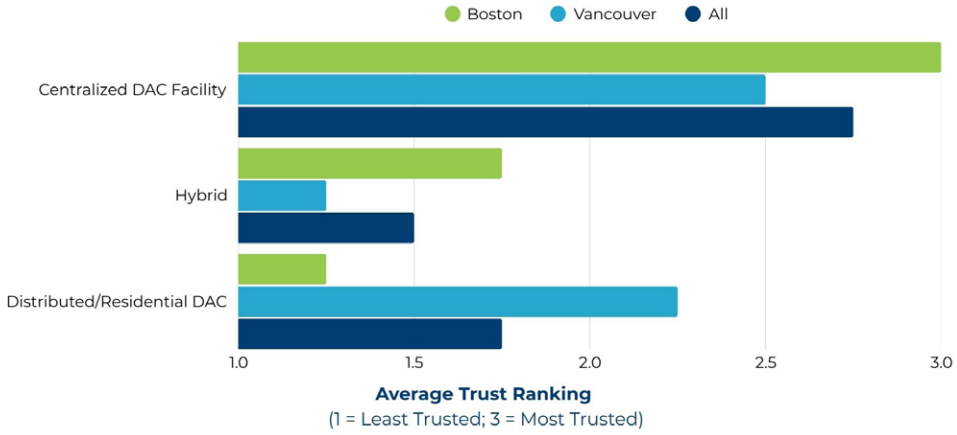

### Example DACCS Rationales

*"1. We think that long lasting products are the safest to put CO2 for the longest time. 2. Centralized DAC facility is centralized, more isolated, long term jobs, and requires short term construction. 2. Federal agencies create uniform standards, and have the resources. 4. Community groups because people are central to the discussion, and cooperation of the people to be successful."*
**–Boston Participant**

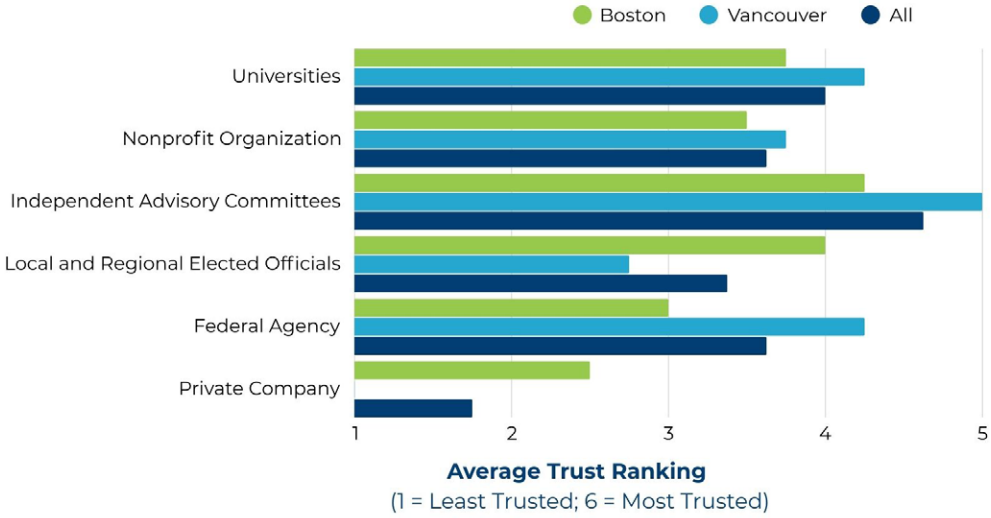
*"Least trust private BUS & GOV. Siting- centralized "one stop shop." Dev & Reporting - level of expertise & level of communication, Advisory - scientists on to/to provide unbiased data."*
**–Boston Participant**

*"Solid-Sorbent-Based Sequestration + long lasting products. The advantage of Residential/Distributed DAC (recycling systems already in place) you trust your community, although the costs are transferred to the community members which is unfortunate. Federal agencies (vast resources, enforcement, data availability, uniformity of standards). Experts (joint attributions by indigenous community & scientists), these two are not mutually exclusive) We did not like any involvement of local industry."*
**–Vancouver Participant**

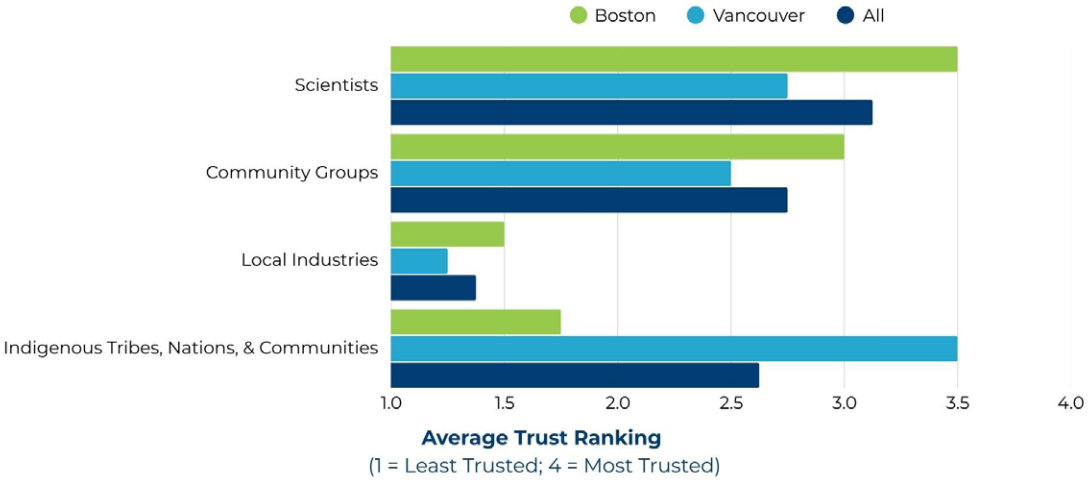
## DACCS: Siting




## DACCS: Development & Reporting




## DACCS: Advising



## SUMMARY & INTERPRETATION

The CDR Plan exercise provides insight into how participants think about institutional trust and governance arrangements for emerging climate technologies.

**1 |** Across both Boston and Vancouver, participants placed greater trust in public, academic, and independent institutions than in private industry. Universities and scientists were frequently viewed as credible leaders for research and advisory roles because participants associated them with expertise and independence.

**2 |** National waters were preferred over international waters for OAE and centralized facility were the preferred over hybrid and decentralized choice for DACCS.

**3 |** Government agencies and independent advisory committees were often seen as appropriate actors for oversight and reporting, particularly where environmental risks were involved.

**4 |** In contrast, private companies were frequently ranked lower in trust. Participants' rationales often referenced concerns about profit motives or conflicts of interest when private actors are responsible for oversight or advisory functions.

**5 |** Together with the findings from the Hopes and Concerns exercise, these results indicate that participants evaluated carbon removal technologies not only in terms of technical performance but also in terms of institutional legitimacy and governance structure.

**6 |** Participants repeatedly emphasized that responsible deployment would require credible expertise, regulatory oversight, transparency, and involvement of affected communities.

# III. Preliminary Results

# Synthesis & Analysis

This section provides synthesis and reflections from the project co-investigators, including a summary of key findings, responses to expert feedback, exploration of future research questions, integration of pTA in CDR governance, and recommendations for next steps.

# Summarizing the Key Findings

MAHMUD FAROOQUE (PI)

The Boston and Vancouver forums offer a chance to explore and compare informed and deliberated public opinions on climate remediation, with a specific focus on CDR technology research and governance. Across both forums, 113 participants engaged in discussions to explore climate solutions, evaluate carbon removal technologies, and consider governance frameworks for potential adoption. Although the demographic makeup of the Boston and Vancouver groups varied in some respects, particularly in age range and ethnic diversity, participants in both locations shared several characteristics, including relatively high educational levels, residence in coastal metropolitan areas, and strong concern about climate change. A few consistent patterns emerged across the forums.

## 1. Participants approached climate solutions through a portfolio perspective

Across multiple exercises, participants consistently emphasized the importance of pursuing **multiple climate solutions simultaneously** rather than relying on any single approach. During the open framing discussions and the climate remediation planning activity, participants often described climate mitigation as requiring a mix of strategies across energy systems, carbon removal, climate adaptation, and broader societal changes. This "portfolio approach" was seen in both group-level activity board results and individual workbook responses. Participants also emphasized that climate solutions should be **customized for specific geographic and social contexts**. Discussions often pointed out that different regions may need different combinations of solutions based on environmental conditions, infrastructure, and societal priorities.

**These results suggest that participants favored a multi-pronged system-level approach at the national level, implemented through regionally, economically, and socially suitable solutions.**

## 2. Environmental impacts were a central concern when evaluating climate technologies

Across both forums, participants consistently assessed climate solutions based on their potential environmental impacts. In discussions about energy technologies, participants often raised concerns regarding resource inputs, land use, infrastructure needs, and waste. Likewise, when assessing carbon removal technologies, they frequently concentrated on potential environmental impacts.

- **For Ocean Alkalinity Enhancement (OAE)**, concerns most often focus on impacts on marine ecosystems and uncertainties about changing ocean chemistry. Participants frequently described OAE as an intervention in complex environmental systems and stressed the need for thorough research before large-scale deployment.
- **For Direct Air Capture with Carbon Capture and Storage (DACCS)**, concerns more often relate to energy demand, infrastructure size, and resource use. Participants often described DACCS as an industrial system whose impacts depend on energy sources and technological scalability.

> *These discussions indicate that participants often evaluated climate technologies from a systems perspective, considering environmental impacts alongside technical performance.*

## 3. Unknown effects were the most important governance consideration for CDR

When participants were asked to rank considerations for CDR governance, unknown effects were identified as the highest priority in both forums. Participants highlighted the importance of understanding potential ecological, economic, and social impacts before deploying carbon removal technologies.

**Concerns about unknown effects included:**

- impacts on environmental systems
- unintended economic consequences
- global equity implications
- disparities between developed and developing countries

Participants often said that decisions about CDR should only be made when backed by solid scientific evidence and high confidence in the results.

> *These results indicate that participants want more research into CDR technologies and their environmental, economic, and social impacts to address deployment concerns.*

## 4. Participants prioritized adaptation and emissions reduction over carbon removal

When participants created climate remediation plans, they consistently dedicated the most resources to adaptation strategies, followed by energy system solutions.

**Across both forums:**

- Adaptation to climate change received the largest investment.
- Carbon dioxide removal attracted the least investment.

Participants often justified these choices by emphasizing the need to address immediate and tangible climate impacts, such as water access, agricultural resilience, and heat adaptation. Within the carbon removal category, participants generally preferred nature-based methods, such as forestation and wetland restoration, over technological options like DACCS and OAE. They often cited environmental co-benefits and familiarity with natural systems as reasons for this choice.

> *These results indicate that participants were eager to proceed with known, proven, and effective solutions to climate change*

## 5. Participants expressed conditional support for carbon removal technologies

Although there was relatively low investment in carbon removal during the remediation planning process, participants did not completely reject CDR technologies. Instead, participants often expressed conditional support. Many indicated that carbon removal technologies could help address climate change, but stressed that deployment should only happen under specific conditions.

**These conditions frequently included:**

- extensive research and testing
- strong environmental monitoring
- transparent governance
- credible oversight by trusted institutions

Participants often described CDR technologies as part of a larger climate mitigation portfolio rather than as standalone solutions.

> *These perspectives suggest that participants saw CDR as solutions that might be needed in the long run, requiring more research and evaluation, but in proportion to the urgent need for immediate climate action involving known and proven remediation strategies.*

## 6. Institutional trust played a central role in governance preferences

When participants assessed governance arrangements for hypothetical CDR projects, they consistently showed more trust in public, academic, and independent institutions than in private industry.

**Across both technologies and locations, participants most often named the following actors as trusted leaders:**

- universities for research and development
- scientists as expert advisors
- federal agencies for oversight
- independent advisory committees for monitoring and reporting

Indigenous communities and affected stakeholders were also frequently identified as important contributors to governance processes. In contrast, private companies and industry players were consistently viewed as some of the least trusted institutions for managing carbon removal projects. Participants often mentioned worries about profit motives and conflicts of interest when explaining these ratings.

> *These results show that, at this stage of CDR development, which is characterized by high uncertainty, participants trust government, university, and community-led research and development efforts more than private efforts, which were seen as primarily motivated by market and profit incentives.*

## 7. Geographic context influenced emphasis but not overall patterns

Although Boston and Vancouver participants sometimes highlighted different aspects of climate solutions and carbon removal technologies, the overall patterns seen in the forums were generally consistent. Boston discussions more frequently emphasized governance structures and institutional oversight, while Vancouver discussions more often highlighted environmental systems and ecological impacts. However, at both locations, participants showed similar reasoning patterns about the need for multiple climate solutions, careful assessment of environmental impacts, and credible governance plans.

> *These findings suggest that shared concerns about climate change solutions beyond national borders can be approached differently depending on the region's geography and political economy.*

## Overall Observation

Taken together, the Boston and Vancouver forums reveal that participants approached climate technologies in a nuanced and thoughtful manner. Instead of focusing only on technological performance, participants often considered how different solutions interact with environmental systems, social institutions, and governance frameworks.

These findings indicate that participatory technology assessment offers valuable insights into how the public thinks about emerging climate technologies when they are given chances for structured discussion and informed deliberation.

# Responding to Expert Feedback

BY AMANDA BORTH

After completing the first round of data analysis, the project team held four **1.5-hour results webinars on Tuesday, October 21st, and Wednesday, October 22nd, 2025.** The purpose of these webinars was to share initial project findings with expert stakeholders and gather their feedback on which questions should be explored further using the data in subsequent analysis rounds. A total of 50 expert stakeholders from various sectors participated in the webinars, mostly representing academia or NGOs. Below is a summary of the key questions categorized into three possible actions: research, replication, and socialization.

## RESEARCH

During the results webinar, participants raised several questions that can be addressed using the current dataset. First, webinar participants sought to understand forum participants' perspectives and rationales regarding different climate change solutions. Second, they were particularly interested in the factors and reasons participants used to decide how much trust to assign to the various actors considered in their CDR Plans. Third, participants noted that in Session 1, forum members ranked unknown effects as the top priority for CDR considerations, and they frequently emphasized the need for more education on CDR to promote informed decision-making among both the public and experts. Consequently, they asked, "What does the public need/want to know about CDR?" Fourth, they were also curious about differences among groups—specifically, why forum participants responded differently to OAE versus DACCS, especially regarding trust and framing. Additionally, they wanted to understand why responses from Boston and Vancouver forum participants varied across different activities.

**Pursuing these questions would be a valuable next step in research, which can be accomplished using the existing dataset. Results would offer important insights to guide current and future research and the responsible development of CDR.**

## REPLICATION

The webinar participants expressed a strong interest in conducting these forums across more diverse demographic and geographic locations to build a more robust dataset of insights. This includes the need to incorporate more Indigenous perspectives into the dataset. Some webinar participants also expressed interest in conducting these forums for other CDR methods, such as ocean iron fertilization (OIF). Some experts and stakeholders encouraged our team to connect with existing efforts and projects investigating similar governance and engagement questions and host more forums to expand the project's impact. Finally, a few webinar participants raised project and program evaluation questions, wanting to know how the forum methods may have affected participants' responses and whether the forums were achieving the intended outcomes and impacts.

**Overall, webinar participants acknowledged the value of this project's work but noted that it fell short of fully meeting expert stakeholders' needs due to limited demographic, geographic, and technological scope. They emphasized the need for more CDR pTA forums with additional research questions, including evaluation. We note that replicating the forum in other locations will be a cost-effective approach since program materials and protocols have already been developed.**

## SOCIALIZATION

Webinar participants also raised various questions that were outside the scope of this pTA project but are still helpful for future public engagement efforts. These included many methodological and procedural questions. Although the project team did their best to communicate answers to some of these questions in advance, a few participants asked both curious and critical questions about the methods used to design, develop, and conduct the public forums.

**Overall, these questions indicate a broader need to inform, educate, and socialize experts and stakeholders on public engagement and participatory technology assessment methodologies to fully convey their value proposition and incorporate them into future research and practice.**

# Expanding Social Science Research on Public Engagement

BY DAVID TOMBLIN

**Question 1:** Given that participants' reported familiarity with CDR significantly increased after participating in the forum, why wasn't there a significant increase in the perceived importance of CDR?

There are the seeds for two possible answers that aren't mutually exclusive within the data generated by this project, but would require further research to confirm.

First, this finding could align with the results of the CDR opening framing focus groups, where participants tended to favor behavioral solutions over technological ones when asked about the best ways to address climate change. The survey results might suggest that people generally still prefer behavioral solutions, which has implications for how CDR technology implementers should approach its application. Exploring how to get the public to value CDR alongside behavioral solutions would be useful. This issue is also linked to the public's perception that technological fixes lead to moral hazard, addressing symptoms rather than root causes. Another area for research is examining how the U.S. cultural focus on individual social responsibility, rather than systemic solutions, influences people's preference for behavioral approaches.

Second, this finding might also be explained by participant preferences for a portfolio approach to climate mitigation and adaptation identified in the forum. Are participant preferences for the portfolio approach an artifact of the forum design, or is there evidence for this elsewhere? If there is broader public support for this approach beyond these forums, it could help explain the relatively muted shift in the importance of CDR in the post survey. Understanding this relationship and whether the portfolio approach generally has wider appeal has implications for how CDR is positioned as a technology. It might be beneficial for the CDR community to start building partnerships with other stakeholders in the climate change space to create portfolio coalitions that might gain broader support than single solution or management approaches.

**Question 2:** How does using Socio-technical Systems approach to Open-framing methods influence participant thinking about CDR technology?

This question builds on question 1 but emphasizes the open framing method itself. The forum results provide initial evidence that open framing methods using a socio-technical systems framework help participants think about a topic differently than they would otherwise. However, to answer this question more definitively, a series of experimental focus groups would be necessary. Conducting an experiment that compares socio-technical systems frameworks to focus groups without this approach would give us a clearer understanding of how the socio-technical systems approach to open framing impacts participant thinking.

**Question 3:** Does the public, like many technical experts, use the deficit model of communication to explain and approach climate change issues? And if so, how is their use of it related to the ways technical experts and traditional science communicators use the deficit model of communication?

It's interesting to see that the public often repeat the deficit model approach to communication when promoting effective decision-making, gaining support, and explaining funding and implementation strategies. These points raise the two questions above. Answering these questions influences how well dialogic models of public engagement work overall. If the public also adopts the deficit model, it may mean that those using more dialogic communication methods need to use self-awareness strategies to help the public distinguish between dialogic approaches and deficit model education methods. It's not enough to expect the public to naturally adopt dialogic methods just by participating in deliberative exercises. Overall, to improve dialogic public engagement, we need to understand how the deficit model of communication is reinforced in public discussion.

**Question 4:** How does the public perceive and understand complex environmental management approaches such as adaptive management and portfolio approaches?

Participant language shows they are explicitly using (Portfolio Approach) and implicitly employing (Adaptive Management) to address complex environmental management strategies. As managing climate change becomes more complicated, public engagement forums need to adapt to this complexity. It is essential to understand how the public perceives and understands these strategies to communicate them effectively and encourage dialogue during public engagement activities. Studying how participants engage with these concepts will help us create better future forums.

# Integrating Participatory Technology Assessment into Governance Pathways

BY ANNA-MARIA HUBERT

## Justifications for pTA for the Governance of Emerging Environmental Science and Technology

Emerging environmental science and technologies, such as CDR, are increasingly central to environmental governance as potential "solutions" to threats like climate change. At the same time, they have the capacity to reshape environmental futures, generating new forms of environmental risk, creating conditions of scientific uncertainty, and potentially producing significant distributive consequences for present and future generations. Democratic governance in this context requires more than technical expertise and inputs. It calls for public access to information and substantive public engagement that goes beyond formal notice-and-comment procedures or limited stakeholder consultations. Moreover, such engagement must occur sufficiently upstream to shape research and technology trajectories, regulatory design, and broader environmental policy and governance pathways, rather than merely responding once a series of decisions are largely locked-in.

The justification for including the general public in decision-making about environmental science and technology is also grounded in normative commitments that reflect the democratic and rights-based foundations of this area. Principle 10 of the Rio Declaration affirms that individuals shall have access to environmental information held by public authorities and that environmental issues are best handled with the participation of all concerned citizens, at the relevant level. Within the framework of the human right to science, as guaranteed under Article 15 of the International Covenant on Economic, Social and Cultural Rights (ICESCR), governments have duties to ensure access to scientific knowledge, opportunities to participate in scientific advancement, and protection from the harmful effects of scientific applications. In particular, the Committee on Economic, Social and Cultural Rights has clarified that a "core obligation" under this right requires states parties to "develop a participatory national framework law on this right that includes legal remedies in case of violations, and adopt and implement a participatory national strategy or action plan for the realization of this right that includes a strategy for the conservation, development and diffusion of science" (CESCR, 2020).

pTA is a valuable method for informing publics and gathering public views, because it operationalizes participation in a structured, deliberative, and anticipatory manner. In decision contexts characterized by scientific uncertainty, contested values, and complex risk–benefit tradeoffs, pTA creates institutional space for informed dialogue between scientific experts, policymakers, and diverse publics. By making expert framings contestable and surfacing embedded value judgments, pTA contributes to epistemic justice and more reflexive decision-making. Early, structured deliberation can increase transparency, reduce polarization, and build trust in governance processes, thus helping to contribute to more adaptive and precautionary environmental regulation. In doing so, it helps operationalize largely procedural environmental rights and principles embedded in existing law and governance.

## The Challenges of Integrating pTA into Existing Governance

Yet, despite these justifications and normative conditions, meaningful and early public engagement in the governance of emerging environmental science and technologies remains uneven in practice. There has also been limited attention to how the outputs of public deliberation are actually integrated into governance frameworks. Where models do exist, integration is often treated as a final step, rather than as a deliberately designed interface between deliberation and decision-making (Kaplan et al., 2021).

Integration may be more challenging because of the complexity of pTA, which is not simply a method for gathering public preferences, but instead produces situated, reasoned, and value-specific judgments about emerging technologies under conditions of uncertainty. These features complicate translation into governance pathways, which also may be procedurally set or legally or jurisdictionally constrained. The challenge, therefore, is not merely whether PTA findings are "taken into account," but how, where, and in what form they can meaningfully shape governance without overstating their representativeness or diluting their deliberative richness.

## Integration of Project Results

The initial ambition of this project was to begin developing concrete approaches to integration of pTA into governance. However, due to a subsequent funding shortfall, the project's scope had to be reduced, so that much of this work must be left for another day. Nevertheless, some early conclusions can be made in respect of this project.

For example, in the open framing and case study exercises, participants expressed a preference for governance of CDR as part of a systematic and integrated approach. They focused on interactions between different climate technologies as part of a "portfolio of solutions" approach, and often considered how different solutions would work across different geographic and cultural contexts. This focus demands cooperation and coordination across different levels of governance and actors, that requires further study and arguably does not presently exist.

The results also showed that unknown effects are the highest-priority concern in relation to CDR, and that research funding should be directed toward supporting decision-making in this area. This finding raises broader questions, not only about the overall availability of research funding, which is often emphasized in the policy literature, but about how funding is allocated and whether it addresses the areas of greatest public concern. Private funding, in particular, may not always align with these priorities, as it may focus on proof of concept or quantifying removal amounts to strengthen the business case for specific CDR methods, rather than on addressing environmental risks and uncertainties. This dynamic may generate informational asymmetries that later become barriers to public acceptance and the responsible implementation of the technology.

In addition, participants' CDR plans revealed a preference for universities, federal agencies, and scientists as the most appropriate actors for research, oversight, and development, while industry and the private sector were the least trusted. This perception, however, does not reflect the current landscape. CDR is advancing simultaneously across multiple phases, some approaches remain in early research, others are in pilot phases, and some are moving toward large-scale deployment. Moreover, private actors are leading significant portions of research, development, and early implementation. This misalignment raises important governance questions about how public expectations and institutional realities can be better aligned so that CDR governance reflects both who is driving the field and who is trusted to govern it responsibly? The gap suggests the need to strengthen accountability, transparency, and mechanisms for public oversight of R&D in order to build durable public confidence.

## Conclusion and Future Directions

We come full circle, recalling that this is an interim report of an incomplete effort. This project began during a time when a focused push to enhance CDR technology research and development was getting underway. However, the main accomplishments of that effort were primarily in technology research, testing, and demonstration, while studies on social implications and public engagement lagged significantly behind. Even a small project like ours faced difficulties in securing funding to achieve modest goals. Despite these challenges, our interim results clearly show that pTA can be an effective tool for anticipating societal considerations of CDR and for integrating these insights into research governance at various stages and levels to make adjustments and course corrections while these remain possible. Moving forward, we intend to share our interim findings broadly and purposefully, aiming to build on our current progress, to grow social capacity alongside technical achievements.

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