SMART CDR Competition Mentor Panel Sessions Q&A

Q: What communication approach do you recommend for conveying highly technical information about our solution?

A: Use visuals that clearly break down steps, ensuring they are interpretable by all, including those with color blindness. Keep the technical section concise and accessible, focusing on key data, formulas, and the technology's impact on CDR. Avoid jargon and complex language. If technical terms are used, consider adding definitions in the footnotes. End with a strong, clear sales pitch.

Q: We plan to write a 5000-words paper in the format of a full-paper (original article). Is this an effective communication? Or is it better to follow the three sections outlined in the official rules document (i.e., Section 1: Background, Theory, and Method; Section 2: Progress and Preliminary Findings; Section 3: Next Steps)?

A: Follow the recommended structure to help evaluators effectively compare projects. While adhering to the Rules Document, teams are encouraged to present creatively, ensuring clear organization. Start with a strong introduction that summarizes the problem and technology, followed by well-defined sections, each with a brief introduction outlining its content. Consider framing the problem from a user/customer perspective to engage the audience, and include details on risks, gaps, and technology suitability. Bullet points can help break up lengthy text.

Q: Our team has completed the theoretical research on our direct air capture MRV approach, but we have not modeled or tested it. Do you recommend that we focus on explaining to reviewers (and others) what we have already completed (theory) or what we plan to do as next steps (experimental)?

A: Both aspects should be included and given equal emphasis. When outlining the next steps, clarify how your insights have shaped the revised approach and how your strategy has evolved from the original plan.

Q: Machine learning AI requires a lot of time and quality data. Are there alternative data analysis techniques other than ML that you would recommend as an initial step until we have the data quantity and quality to run our ML approach for measuring CO2 remotely?

A: The initial step should involve downloading open-access data and developing your models based on this information. Numerous open-access MRV datasets are available online from various projects, such as the real-time data published by the Shell Quest project in Alberta, Canada. Industry should focus on improving the efficiency of data collection processes.

Q: Our team is working on having a model that predicts C as an option behavior of CO2 over porous materials. The properties of the porous materials could affect the CO2 capture, and we have an idea to

have a model that could predict the behavior of air capture emissions, however the model may not be accurate. Should we have a separate model for each type of mixture and the pure behavior?

A: Understanding both the pure CO2 and the composition of your mixture is essential, as each will offer distinct insights. The recommendation is to review relevant literature, such as the work of Dr. Arvind Rajendran's team at the University of Alberta, known for their expertise in modeling. Begin by evaluating the key parameters, assumptions, and their impact. While the choice of parameters is at your discretion, it is important to provide a clear rationale and background research to justify the selected method, pathway, and assumptions.

Q: We are focusing on ocean alkalinity enhancement and ocean fertilization, using a combination of two methodologies that have been used in literature. What is the most environmentally friendly method for CO2 capture that can be enhanced through our project?

A: Conducting a literature search and assessing what other marine CDR organizations are doing are important steps. Consider the life cycle assessment of the material itself. As your project develops, be sure to explain how the selection of materials aligns with the identified priorities and how those factors influenced your final decision.

Q: Are there any sources of high-quality satellite images for CO2 and equivalent?

A: The Global Carbon Atlas map includes real-time CO2 concentration data, as well as data on temperatures and wind speeds.

Q: Regarding the development of MRV technologies and protocols, how does the Department of Energy (DOE) assess and prioritize projects that can provide transparent, verifiable tools and protocols for measuring, reporting, and verifying carbon dioxide removal?

A: DOE has published many solicitations related to carbon removal, with ones in the past primarily focusing on direct air capture. To assess MRV in responses, DOE evaluates the rigor and accuracy of the MRV methodology or protocol submitted, including the appropriateness of the methodology or protocol for the CDR project, as well as the qualifications of the independent third-party verifier. Find more information on DOE's process for evaluation in the CDR Purchase Prize Official Rules Appendix 12.

Q: In terms of integrating carbon dioxide removal with our research area (integrated CO2 adsorption-mineralization (IAM) technology with data analytics), we are not sure how to integrate TEA and LCA together. Can you provide suggestions on how we can design the integrated framework that encompasses LCA, TEA, process simulation, and optimizations?

A: Integrating LCA with TEA analysis is beneficial, as both models share many identical assumptions. The general idea is to 1) establish a mass and energy balance model; 2) consider the processes in categories, such as utility (electricity, water, etc.), equipment, raw materials, construction, and transportation; 3) calculate the cost and emissions associated with removing 1 ton of CO2e for each category; and 4) combine the cost elements to develop the TEA model and the emission elements to develop the LCA model. Reviewing this publication could be helpful:

Adapting Technology Learning Curves for Prospective Techno-Economic and Life Cycle Assessments of Emerging Carbon Capture and Utilization Pathways.

Q: How do you balance accuracy and simplicity when performing LCAs for complex products?

A: Simplicity is generally not a virtue for performing LCAs but can help in communicating complex messages and confidence levels. Complexity is inherent in conducting an LCA, but it is important to do so in a structured manner. Stay organized during research and modeling, focus on the key questions, and support claims with transparent, sound science. Justify boundaries, assumptions, baselines, and functional units. Note that subjectivity, such as weighting impact categories, exists in LCA**.**

Q: How do you handle data gaps or uncertainties in LCA, especially when assessing less documented products?

A: Some organizations face challenges with data acquisition, particularly when conducting TEA or LCA on direct air capture processes. While the aim is to reference published literature and industry data, industry reluctance to share data can hinder progress. If the data is unattainable, the study should emphasize the need for increased data sharing in future work. Direct outreach and collaboration with trade associations may help gather necessary industry data. The article on Comparative Evaluation of Chemical Life Cycle Inventory Generation Methods and Implications for Life Cycle Assessment Results discusses the relationship between data, time, and accuracy.

Q: You mentioned using AI to estimate processes around data gaps. What is your experience with accuracy and where do you see room for improvement?

A: There are academic articles that explore this, including 1) Rapid Life-Cycle Impact Screening Using Artificial Neural Networks | Environmental Science & Technology; 2) Machine Learning to support prospective Life Cycle Assessment of emerging chemical technologies - ScienceDirect; 3) AI-powered Framework to Predict Environmental Impacts of Organic Chemicals via Retrosynthesis - Research Collection. Machine learning can be customized using existing LCA data for common industrial chemicals and adding non-common chemicals into the algorithm, although this can result in accuracy uncertainties.

Q: How do you envision the future of regulation impacting carbon accounting and product LCA accuracy? Will regulation on DPP (digital product passport) require companies to increase their product data quality/availability across their supply chain to perform more accurate LCAs?

A: Predicting future trends is challenging, but anti-greenwashing laws are expected to increase, leading to greater accuracy in product claims. The EU has advanced its Green Claims Directive (GCD). Canada has recently passed a law under the Competition Act requiring companies to submit an adequate and proper test for environmental product claims, though formal guidance is still pending. As regulations evolve, they will become crucial in how LCAs and carbon accounting exercises are conducted and defended through substantiated claims. Consumers are likely to demand more stringent regulations and high-quality, transparent claims. These regulations must be robust, with clear cost estimates for implementation. Political implications may arise, such as regulations increasing domestic prices, leading to imports from countries with less stringent rules. The Carbon Border Adjustment Mechanism (CBAM) is being considered by some countries, applying tariffs on imported goods based on estimated emissions to level the playing field and discourage the purchase of high-emission products. The EU's provisional CBAM offers valuable insights as this new policy instrument develops.

Q: Is there a CBAM coming to Canada or North America?

A: The Canadian government has previously discussed a CBAM, but details remain unclear, and no immediate action is expected. As the EU's CBAM progresses, other countries, including the U.S., are exploring similar concepts, with bipartisan interest emerging.

Q: How should we account for life-cycle emissions associated with the storage medium when evaluating CDR methods? For example, when storing CO2 in depleted oil and gas reservoirs, demolished concrete, or steel slags.

A: Colorado has numerous abandoned and plugged oil wells, including "ghost wells" that are unidentified. Geomagnetic methods can map wells with intact casings, while methane monitoring can detect leaks in wells without casings. Challenges in using depleted oil fields for storage include methane leaks and concrete degradation. In geochemical CDR, only the acid-base component can be captured by converting lime or calcium silicate in concrete into a carbonate to absorb CO2. However, the energy used to produce concrete and waste materials will always exceed the energy captured from the base component.

Q: How can the counterfactual for enhanced mineralization be efficiently estimated, i.e., the amount of carbon that would naturally be absorbed by minerals or industrial waste without CDR interventions?

A: Geochemical CDR is influenced by particle size and CO2 concentration, with chemical processes also enhancing the rate. However, all processes require energy input, making net CDR challenging for higher-energy systems. On a lab scale, dissolution rates can be measured and experiments conducted to optimize CO2 concentration and particle size for CO2 removal. Larger systems introduce more complexity. The key distinction between carbon mineralization and enhanced rock weathering or ocean alkalinity enhancement lies in the system type: carbon mineralization is a closed loop, likely forming carbonate minerals, which simplifies MRV tracking, while open systems involve more complex interactions with natural biochemical cycles. The impact of enhanced rock weathering and ocean alkalinity on these cycles remains uncertain.

Q: During its lifetime, concrete naturally takes up CO2. By performing carbonization, e.g. injecting CO2 in concrete blocks, before building a structure, it inhibits the natural carbonization happening over its lifetime. How can this be efficiently monitored and accounted for?

A: Measuring atmospheric CO2 and [The Keeling Curve] is challenging, and while natural processes play a role, they are unlikely to solve the problem. Their impact is small and may fall within the error margin measurement.

Q: In OAE-related MRV, I believe economic aspects are important, but I would like to know if there are other crucial elements. How should we balance accuracy while minimizing MRV costs?

A: Efficiency, accuracy, and further development of tools are needed. Direct measurement methods in nature are limited, leaving models that may introduce errors from measurement, model assumptions, and input parameters. The primary subsurface challenge is the lack of ground truth, which can only be confirmed through drilling wells. It's a challenging situation, where better models lead to higher costs. For OAE, a key challenge is obtaining reliable MRV signals, as concentrated alkalinity in small areas is easier to measure, however risks reducing efficiency through carbonate precipitation. To maximize CO_2 sequestration, a dilute approach on the upper water column is preferred. Models are essential in navigating these challenges. The State of CDR Report is a global assessment of the state of CDR and the gap we need to close.

Q: How do environmental phenomena like acid rain, ocean acidification, or other climate-related changes affect the permanence of carbon storage?

A: Acids that react with Earth's natural buffering systems, such as CO_2, alkalinity, and carbonate minerals, release CO_2. Sources of acid include nitric acids from fertilizers and sulfuric acids from coal emissions. Neutralizing acid mine drainage also releases CO_2 due to its interaction with the carbon system. Ocean acidification has two components: alkalinity enhancement and enhanced rock weathering, which benefit organisms and calcifiers. The dissolution of shelly animals neutralizes CO_2, however, can harm organisms. Proposals for ocean alkalinity enhancement near coral reefs aim to balance CO_2 removal and protect calcifiers. Temperature and salinity also influence these processes and CO_2 uptake.

Q: For this competition, in terms of Monitoring, Reporting, and Verification (MRV) tools and protocols specifically for enhanced mineralization, what are the key aspect to focus on, especially considering the absence of robust and standardized MRV practices to quantify and compare various enhanced mineralization solutions?

A: Given the lack of MRV protocols specifically for geochemical CDR (including enhanced mineralization), it is useful to reference adjacent protocols from related fields. For example, in mining environments, look at protocols for sampling rocks and water from tailing facilities; for enhanced rock weathering on agricultural fields, refer to protocols for sampling soil and pore water in agricultural research; and for ocean alkalinity enhancement, consider protocols from oceanographic expeditions. Government agency protocols, such as those from the U.S. Environmental Protection Agency (EPA), may also be valuable. MRV protocols must address quality control, quality assessment, and sampling/instrumental analytical errors. Consider spatial heterogeneity and temporal variability (e.g., seasonal changes) in both baseline and post-treatment measurements. Larger, more open systems may present weaker signals (e.g., changes in alkalinity) due to dilution, though this dilution can enhance CO_2 removal efficiency. Other key aspects include:

- Calibrating mineralization signals to quantify mineralization extent.

- Assessing mineralization effects based on host mineralogy, injected fluids, post-injection pore fluid composition, reactive surface area, and long-term fluid exposure.
- Quantifying optimal mineralization conditions across different geologic environments.
- Developing a selection tool for composition, fluid conditions, and expected measurement signals to guide location-specific fluid and tool selection.