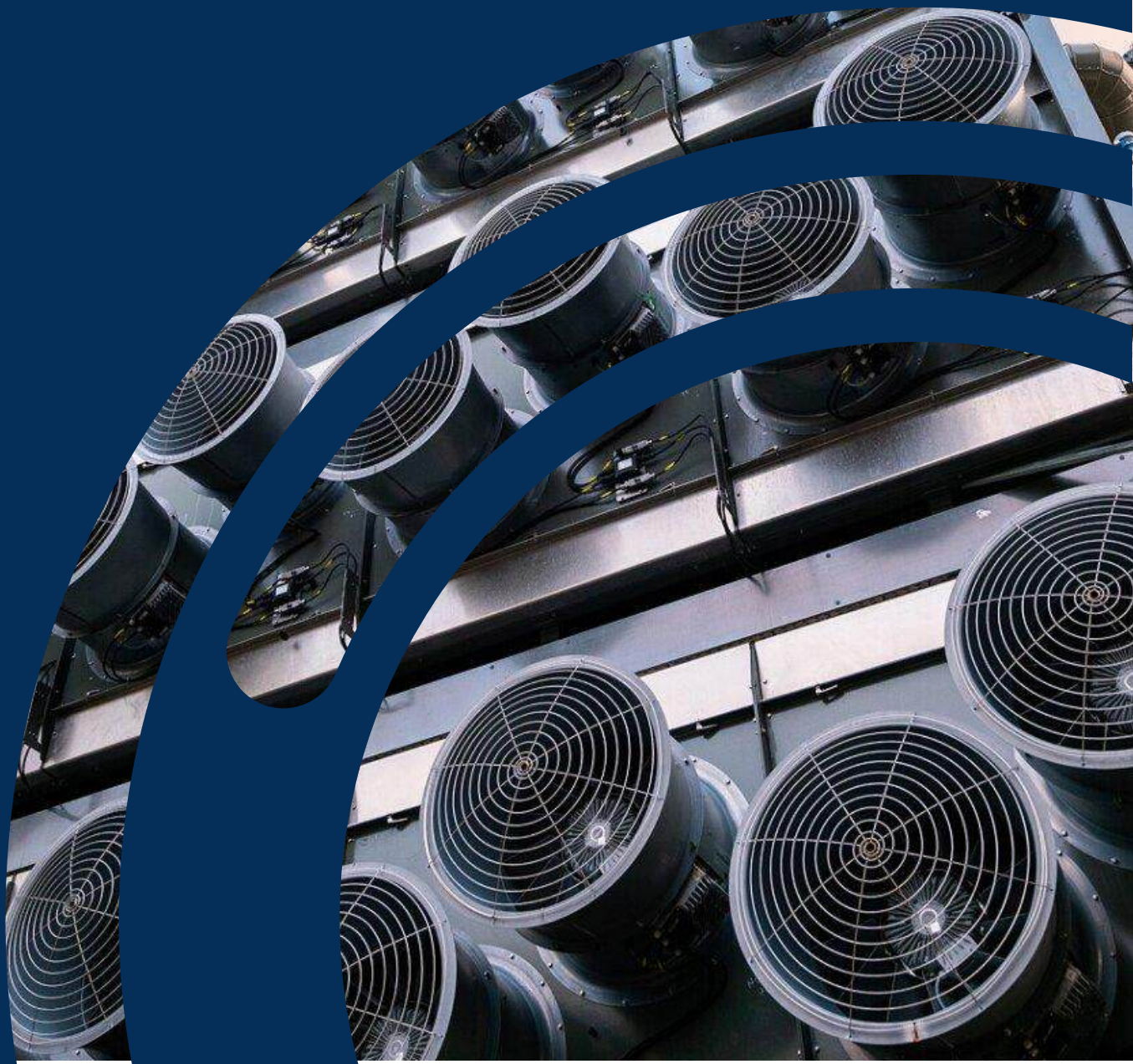
MISSION INNOVATION

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Ministry of Economy, Trade and Industry

MISSION INNOVATION CARBON DIOXIDE REMOVAL MISSION
TOKYO WORKSHOP II SUMMARY

Carbon Dioxide Removal: Exploring Practical Pathways for Innovation and Scale-up

10-11 September 2026, Tokyo



Workshop Summary Report

Contents

Day 1 2
Welcome Address 2
Keynote: CDR Today 4
Keynote: Novel CDR and developments towards COP31 6
Keynote: Novel CDR Markets 8
Market Perspectives 10
Non-technical Enablers 14
Keynote: Geographical Advantages and Constraints for Scaling CDR 18
Technology Enablers 21
Breakout Discussions: Strategic Dimensions of CDR Scale-up 25
Breakout A: Demand Signals, Market Confidence, and Implications for CDR Developers 25
Breakout B: Demand Signals, Market Confidence, and Implications for CDR Buyers 26
Breakout C: Technology Readiness, Demonstration, and Implications for CDR Scale-up 27
Day 2 28
Keynote: Accelerating Materials Innovation for Clean Energy 28
Keynote: Materials Innovation to Scalable Carbon Removal 29
Keynote: The 2027 IPCC CCS & CDR Methodology Report - state of play and implications for CDR deployment 32
Building Trust at Scale: Standards, Market infrastructure, and Risk Management 34
National Policies and Activities 37
MI CDR “SMART CDR Competition”: The Journey of a Japanese Start-up 43
From Insights to Action: Building CDR Roadmaps 44
Panel Discussion: Moving CDR Forward Globally 49
CDR Mission Key takeaways from the event 55
Closing remarks 56
Appendix 1: Program Outline 57

Day 1

Welcome Address

Mami Fukuchi,
Deputy Director-General for Innovation Policy, Innovation and Environment Policy Bureau, Ministry of Economy, Trade and Industry

Following last year`s CDR Mission workshop in Tokyo, momentum has continued to grow across technology innovation, policy development, and market creation. This year's workshop brings together more than 100 participants from government, academia, industry, and the investment community. While engagement in CDR is expanding, significant challenges remain, and scaling up CDR will require continued innovation, stronger demand signals, and international cooperation.

The workshop provides an opportunity to explore the evolving CDR landscape and identify practical pathways toward deployment at scale. Our discussions will address not only technological development, but also the policy, investment, and social considerations necessary to enable CDR. No single country or stakeholder can achieve this alone, making Mission Innovation an important platform for strengthening international collaboration in clean energy innovation.

Japan also sees considerable potential in the growing diversity of CDR technologies and in the role of startups. New ideas, technologies, and business models can accelerate innovation and deployment. Japan will continue to support innovation, strengthen international partnerships, and foster an environment where diverse technologies and businesses can contribute to our shared climate objectives.

Joanna Drake,
Deputy Director-General of DG Research & Innovation, European Commission

CDR remains at an early stage, and no single country can bring these technologies to scale alone. Mission Innovation provides a unique platform for countries and institutions to combine their ambition and resources, while the CDR Mission applies

this collaboration to one of the most challenging areas of climate technology. For technologies that are still young and capital-intensive, international cooperation is essential to bridge the gap between today's pilot projects and the scale required for meaningful climate impact.

Industrial carbon management, including carbon removals, is a firm priority for the European Union. European Commission modelling for the EU's 2040 climate target indicates a need to capture around 280 million tons of CO_2 annually by 2040, rising to 450 million tons by 2050, with an increasing contribution from biogenic and atmospheric sources. The EU is pursuing this through a combination of policy measures and research and innovation.

On the policy side, the EU's CDR and Carbon Farming Regulation provides a certification framework intended to support a trusted carbon-removal market, complemented by initiatives to stimulate demand for early projects. On the innovation side, Horizon Europe and the Innovation Fund have already committed more than €330 million to carbon-removal technologies at different stages of maturity. Further support for advanced direct air capture demonstrations will continue, with international cooperation remaining an important part of these efforts.

Moneer T Alsubaie,
MI CDR Co-lead, Sustainability and Climate Change Engineer, Ministry of Energy, Kingdom of Saudi Arabia

For Saudi Arabia, CDR forms part of a broader, technology-inclusive approach to emissions management through a circular carbon economy, based on four complementary pathways: reduce, reuse, recycle, and remove. The CDR Mission focuses on the "remove" pathway and, in particular, on moving CDR technologies from research and demonstration toward deployment at meaningful scale.

The Mission has a clear target of enabling CDR technologies to deliver 100 million tons of net CO_2 removal per year globally by 2030. Achieving this will require progress across the full innovation and deployment chain and close collaboration among governments, researchers, and industry. The Mission therefore works to strengthen understanding of CDR potential, advance R&D in areas such as direct air capture, carbon mineralization, and biomass-based carbon removal and storage, and support demonstration and pilot-scale testing around the world.

The Mission combines cross-cutting activities—covering areas such as CDR mapping, enabling policy frameworks, and innovation initiatives—with technical tracks focused on specific technologies and analytical needs. The Mission is also starting to focus more on enabling frameworks key policy levers that governments can use to accelerate novel CDR. As deployment conditions and resources differ significantly across countries, international collaboration remains central to this work. Saudi Arabia looks forward to advancing these efforts with its Mission partners and to continuing the carbon-management dialogue at the 11th MI ministerial meeting on 11-13 October, during the at Riyadh Energy Week, where emerging CDR solutions and innovators will also be showcased.

Keynote: CDR Today

Morgan Edwards,
Executive Team, State of Carbon Dioxide Removal

The latest edition of the State of Carbon Dioxide Removal assesses where CDR stands today and the role it could play in meeting global climate goals. It covers both conventional approaches, such as afforestation and reforestation, and novel CDR methods. Today, the majority of removals come from conventional methods, at around 2.2 gigatons per year. Novel CDR remains very small by comparison, although it is growing rapidly and attracting increasing attention across research, investment, and demonstration projects.

CDR methods vary widely in technology readiness, cost, and potential. Conventional methods tend to be more mature and lower-cost, while novel approaches range from laboratory-stage technologies to commercial deployment, with some current cost estimates exceeding $1,000 per ton of CO_2. There is currently no single method that combines high potential, low cost, and deployment readiness. A diverse portfolio of CDR approaches will therefore be important, alongside continued efforts to reduce costs and address uncertainties around durability, sustainability, monitoring, and resource requirements.

New modelling undertaken for the report illustrates the scale of the challenge. In scenarios consistent with ambitious action toward the Paris climate goals, median CDR deployment reaches approximately 3.9 gigatons per year by 2035 and 8.8

gigatons by 2050. Importantly, CDR does not replace emissions reductions: around 84% of mitigation at net zero comes from reducing emissions at the source, with removals accounting for around 16%. Both conventional and novel CDR will be needed, with novel approaches becoming increasingly important as physical constraints on conventional methods emerge.

The required scale-up is rapid, but experience with technologies such as solar photovoltaics and electric vehicles suggests that comparable rates of growth have occurred before. While companies are announcing significant ambitions to expand CDR capacity, the current pipeline of actual projects remains below the levels required in ambitious climate scenarios. Strong policy support and robust demand signals will therefore be critical to translate supply-side ambition into deployment. Building the technologies, markets, and capacity required for future CDR needs to begin today.

Q&A

Q：The presentation compared the future growth rate of novel CDR with rapidly scaled technologies such as solar photovoltaics and electric vehicles. Does this comparison refer to the amount of CO_2 mitigated, or to the deployment/capacity of the technologies?

A： The comparison is based on deployment capacity rather than mitigation impact. It illustrates how novel CDR could grow if it were deployed at rates comparable to technologies such as solar PV or electric vehicles. The comparison therefore focuses on the rate of technology deployment, rather than the amount of CO_2 mitigated.

Q：Given that CDR approaches may compete with other mitigation solutions for scarce or limited resources, could caution around resource use potentially constrain early-stage CDR development and deployment?

A： At the current stage, this is not considered a major concern because CDR still represents a very small share of the overall climate mitigation portfolio. For example, only around 3% of investment in climate mitigation startups currently goes toward CDR, suggesting that CDR is not yet crowding out other mitigation activities.

However, as CDR scales, potential competition for limited resources could become more relevant. It is therefore important to start considering which CDR methods should

be scaled and how they should be deployed. CDR should not be viewed as a “panacea” that can simply emerge around the time of net zero; instead, careful consideration of its appropriate role and deployment needs to begin today.

Keynote: Novel CDR and developments towards COP31

Chris Neidl,
Carbon Dioxide Removal Lead, UN Climate High-Level Champions

CDR faces not only an implementation challenge—developing technologies, policies, and finance—but also a broader mobilization challenge. Achieving the scale of CDR required by climate scenarios will demand unprecedented growth, and strong technical or policy solutions alone will not guarantee action. Mobilization requires creating urgency, demonstrating evidence of progress, showing real-world projects and policies, and making CDR relevant to decision-makers beyond the existing CDR community.

CDR advocacy has historically followed an “addition” framework: establishing that CDR is necessary, quantifying how much is needed, developing dedicated policies, and building a CDR community. This approach has achieved significant progress, particularly since the IPCC’s 2018 report, helping CDR emerge as a recognized field and driving substantial diversification of technologies and solutions. However, treating CDR as a separate sector can make political mobilization and large-scale deployment more difficult.

The next phase should increasingly adopt an “absorption “framework, integrating CDR into industries, policies, and concepts that already have momentum. Rather than building CDR as a standalone sector, carbon removal could become a feature of areas such as waste management, concrete, mining, agriculture, green industry, and the circular economy. This also requires strong networks of policy entrepreneurs and intermediaries who can connect CDR expertise with decision-makers in other sectors and institutions.

COP provides a particularly important opportunity for this integration because it creates policy windows, proximity among diverse actors, and a strong implementation focus. Following COP30, the Action Agenda has shifted toward concrete five-year “Plans to Accelerate Solutions.” Many of these initiatives have potential synergies with CDR, particularly around green industrialization, industrial decarbonization, zero

waste, circularity, agriculture, oceans, finance, and capacity building.

CDR 2030, established through the COP30 Action Agenda, provides a platform for embedding carbon removal across these broader initiatives. Looking toward COP31, the objective is therefore not simply to advocate for more standalone CDR activity, but to build relationships and identify where CDR can support existing priorities, allowing carbon removal to become increasingly integrated into mainstream climate and industrial action.

Q&A

Q: How can CDR be positioned within existing projects and national priorities, particularly in countries such as Indonesia where CCS, geological storage, hydrogen, and waste-to-energy projects are already developing?

A: Indonesia presents significant opportunities for integrating carbon removal into existing activities, including through its evolving carbon-market landscape. There is a need for deeper discussion of these opportunities, particularly given Indonesia's potential both for domestic CDR implementation and participation in broader carbon-market initiatives.

Q: What is your view of the recent UNEP report addressing the 1.5°C goal and the role of CDR?

A: The report was described as highly significant because UNEP's institutional standing can help establish CDR as a legitimate and increasingly mainstream component of climate action. Its treatment of carbon removal was viewed as sophisticated and consistent with the need to integrate CDR into broader climate discussions. The speaker stressed that maintaining a credible conversation around the 1.5°C goal increasingly requires consideration of carbon removal.

Q: Could Article 6 of the Paris Agreement act as a catalyst for CDR growth, particularly in developing countries?

A: Yes. Article 6 was identified as potentially one of the major channels for financing carbon removal. Early examples involving countries such as Switzerland, Norway, and

Sweden, as well as initiatives exploring Article 6 relationships with African countries, provide useful precedents. Increasing the visibility of these early activities could demonstrate that Article 6-based CDR transactions are feasible and encourage additional countries and actors to participate.

Keynote: Novel CDR Markets

Tank Chen,
Head of Community & Content, CDR.fyi

The voluntary market for durable carbon dioxide removal has grown significantly since CDR.fyi began tracking transactions in 2019. By the end of Q2 2026, approximately 48.9 million tons of durable CDR had been contracted, with the figure approaching 50 million tons more recently. Microsoft remains by far the largest buyer, accounting for around 76% of all contracted durable CDR, although its share has declined from 81% a year earlier. Importantly, demand outside Microsoft is also growing: more than 918 other organizations have contracted approximately 11.7 million tons, demonstrating that the buyer base is gradually becoming more diversified.

On the supply side, biomass-based approaches dominate contracted volumes, accounting for around 90% of durable CDR contracts. However, contracting does not necessarily translate into actual removal. Delivery—where contracted removal has actually occurred and credits have been issued and transferred—is therefore a critical metric. Approximately 1.7 million tons have been delivered to date, with biochar accounting for around 79% of deliveries. Several large BECCS and DAC projects are expected to begin operations from 2026 onward, which could significantly change the composition and scale of future deliveries. A major challenge is ensuring that large contracted projects reach final investment decision (FID), become operational, and ultimately fulfill existing demand.

Demand remains concentrated geographically and by sector. The United States is the largest buyer market, while the top five countries account for 76% of purchasers. Software, financial services, and CDR intermediaries are particularly prominent. Public procurement is also beginning to emerge. Among companies with Science Based Targets initiative (SBTi) targets, the number purchasing CDR increased from 35 in 2024 to 134 in 2026, but this still represents only around 1% of companies with SBTi targets. Buyers tend to have net-zero targets earlier and are disproportionately

concentrated in North America and Europe and in high-profit-to-emissions sectors such as software and finance.

This leaves significant potential for the next wave of CDR demand. Asia is particularly underpenetrated: around 4,700 of the approximately 13,000 companies with SBTi targets are based in Asia, including roughly 2,500 in Japan, yet the region has only a very small number of durable CDR purchasers today. Other underrepresented sectors—including electrical equipment and machinery, food and beverage processing, construction and engineering, trading companies, and textiles and apparel—could also become important sources of future demand. Expanding participation beyond today's technology and financial-sector buyers will therefore be important for developing a broader and more resilient voluntary CDR market.

Q&A

Q: How can the integration of CDR into existing industries be tracked, given that this may increasingly happen through industrial products and infrastructure rather than conventional carbon-credit transactions?

A: CDR is increasingly being embedded in existing infrastructure and industries, such as wastewater treatment, district heating, horticulture, and mining. Such integration can improve delivery certainty, but projects also need sufficient demand for both the carbon removal and the associated low-carbon products or services.

Q: How can companies in new and currently underrepresented sectors be introduced to the CDR market? Do they require education, and who should provide it?

A: Visibility and transparency are key. When one company enters the CDR market or announces a partnership, competitors and peers often become interested and begin exploring CDR themselves. Publicizing early examples can therefore help attract additional companies and broaden market participation.

Market Perspectives

Tank Chen (Moderator),
Head of Community & Content, CDR.fyi

Erik Rylander,
Commercial Director CDR, Stockholm Exergi, Sweden

Stockholm Exergi is demonstrating how carbon removal can be integrated into existing energy infrastructure rather than developed as a standalone activity. The company already operates a large bioenergy combined heat and power plant in Stockholm using residues from Sweden`s forestry industry. The plant produces approximately 350 MW of renewable heat and 150 MW of renewable electricity and is now being retrofitted with carbon capture technology. Captured biogenic CO_2 will be transported by ship for permanent geological storage offshore Norway. Once operational by the end of 2028, the project is expected to remove approximately 800,000 tons of CO_2 annually.

The project represents an investment of almost €1.2 billion and reached its investment decision in March 2025. Its financing model combines three elements: commercial CDR revenues, EU support through the Innovation Fund, and Swedish state funding. Microsoft serves as the anchor offtaker, purchasing more than 5 million tons over ten years, and nearly two-thirds of the project's first ten years of production had already been contracted at the time of the investment decision. While public support is essential for this first-of-a-kind project, the long-term objective is for market revenues to sustain operations as state support is phased out.

Omar Alajaji,
Advisory Services Sector Manager, Regional Voluntary Carbon Market Company (RVCMC), Kingdom of Saudi Arabia

RVCMC was established to help develop the carbon market ecosystem in Saudi Arabia and the wider region, supporting decarbonization and the Kingdom's net-zero ambitions. Since its establishment in 2022, the platform has traded more than 15 million carbon credits while working to increase market awareness, stimulate buyer demand, and encourage the development of domestic and regional carbon-credit projects. The project pipeline has expanded significantly, with growing interest in carbon removal, particularly biochar.

A key element of RVCMC's approach is its auction model, which combines different types of carbon credits into curated baskets. Over time, these baskets have evolved from reduction credits toward greater inclusion of nature-based and durable removals, allowing RVCMC to stimulate demand for emerging project types while managing overall costs. Projects undergo screening based on recognized registries, credit vintages, and quality ratings. RVCMC is also bringing buyers and project developers together to facilitate offtake agreements and strengthen the broader regional carbon-market ecosystem.

Tadashi Sawamura,
General Manager, Carbon Management Dept. Europe & Next-Generation Energy Div. Energy & Power Solution Group, Mitsubishi Corporation, Japan

Mitsubishi Corporation aims to act as an ecosystem enabler across the carbon market by combining project investment and development, carbon-credit trading, demand aggregation, and broader market-building activities. Its activities cover both technology-based and nature-based carbon solutions, while initiatives such as buyer platforms and coalitions are intended to aggregate demand and provide stronger market signals to project developers.

Japan's emerging compliance framework, including the GX-ETS and the use of credits associated with the Joint Crediting Mechanism (JCM), could create significant new demand, although current price levels may not yet be sufficient to support many technology-based CDR projects. Mitsubishi is therefore also working on voluntary market-building initiatives. In Japan, where corporate participation in CDR remains limited, the Japan CDR Coalition has grown to 91 member companies and has published a Japan CDR roadmap. The initiative seeks to improve understanding of the distinct value of carbon removal, build corporate demand, and provide an industry perspective to policymakers.

Discussion :

Q: What are the most encouraging developments and major concerns in the CDR market today?

A: The emergence of new buyers beyond Microsoft is encouraging and important for broadening the market. However, the pace of large-scale project development remains a concern. Few major projects have reached FID, and clearer frameworks are also needed for how companies can use and claim their CDR purchases.

A: Awareness of CDR remains relatively low in Saudi Arabia, but once buyers understand the concept, interest can develop quickly and project developers respond to demand signals. Biochar in particular is attracting growing attention. The challenge is moving from smaller projects toward the large-scale deployment required by the market.

A: Future demand signals are encouraging, but there is a timing gap between expected demand and developers' financing needs today. With the market having relied heavily on major voluntary buyers such as Microsoft, developers can face difficulties raising capital while waiting for broader demand to materialize.

Q: Will updated SBTi and ISO guidance help translate corporate climate commitments into CDR demand?

A: Updated SBTi guidance is helpful because it provides companies with net-zero targets a clearer pathway for incorporating CDR, making internal discussions easier. The emerging ISO standard also appears promising and may provide greater flexibility for corporate engagement with CDR.

A: Clear standards are essential for building demand because they help companies understand how CDR fits within their sustainability strategies and clarify expectations. This can also give project developers greater confidence that future demand will exist.

A: In Japan, the updated guidance has not yet translated into a noticeable increase in CDR purchasing inquiries. Many companies are still trying to understand the requirements, and technical details remain difficult to interpret, particularly for mid-sized companies with limited internal resources.

Q: How should voluntary and compliance carbon markets interact?

A: Compliance markets will be necessary to secure long-term demand, as the market

cannot rely indefinitely on voluntary commitments. However, voluntary and compliance markets should coexist, allowing companies with ambitions beyond regulatory requirements to continue purchasing CDR voluntarily. Market rules should therefore avoid unintentionally discouraging voluntary action.

A: Compliance markets should complement rather than replace voluntary markets. A well-designed compliance system could actually catalyze voluntary carbon-market activity, including through appropriate use of carbon credits, although the balance between regulatory requirements and flexibility needs to be carefully managed.

A: Japan's GX-ETS has already increased corporate awareness of carbon credits by turning carbon pricing into a business and risk-management issue. Looking ahead, voluntary and compliance markets need greater convergence so that reliable suppliers can serve demand across different markets and jurisdictions without facing excessive complexity.

Q: What are the opportunities and limitations of emerging compliance markets in Japan and the EU?

A: Japan's GX-ETS is already creating demand signals, but current carbon-price levels are not high enough to support many CDR projects. There is therefore a price gap that needs to be bridged. Nevertheless, the scheme is still at an early stage, and emerging buyer interest provides an encouraging starting point.

A: In the EU, recognizing CDR within the emerging framework sends an important policy signal. However, the proposed model provides limited direct market visibility for CDR, and there is a significant funding gap between EUA prices and the cost of high-durability removals such as BECCS and DAC. Maintaining CDR quality while addressing this funding gap will be important.

Q: How can sufficient CDR supply be developed in time to meet future demand?

A: Large-scale CDR requires significant capital and specialized capabilities that many developers do not yet possess. More talent and investment are needed, together with mechanisms that distribute project risks more fairly rather than placing most of the risk on developers.

A: Strong demand signals will encourage supply, but there will inevitably be a lag, particularly for large-scale projects. Market mechanisms such as credit baskets can help gradually increase demand for CDR and provide stronger signals for investment and project development.

A: Projects that have successfully reached FID demonstrate the importance of public-private co-funding and appropriate risk sharing. Neither public nor private capital can carry the full burden alone. In the longer term, stronger demand signals—including the incorporation of explicit CDR targets into countries' NDCs—could provide the certainty needed to scale supply.

Non-technical Enablers

Christopher Toews (Moderator), Director, Energy Innovation Policy, Office of Energy Research and Development, Natural Resources Canada

Yukimi Shimura, Managing Director in charge of Corporate Engagement on GX and Sustainability, Sustainable Business Division MUFG Bank, Ltd., Japan

MUFG views CDR as a promising but still nascent industry, particularly in Japan. While the bank already has significant experience in advisory and project financing for CCS projects in Europe and North America, many CDR technologies and business models are not yet mature enough for conventional bank debt. Developing workable and bankable business models is therefore an important prerequisite for larger-scale debt financing.

MUFG is engaging with the CDR ecosystem before projects reach the conventional debt-financing stage. Its activities include supporting business-model development for a Japanese DAC startup developing membrane-based technology, investing in another DAC startup through its venture-capital affiliate, purchasing domestic carbon credits through multi-year agreements, and participating in programs covering CDR, CCUS, and CCU. Through these activities, MUFG aims to understand emerging technologies and business models while helping create an enabling environment and

ecosystem that can eventually support conventional financing.

Marianne Bruvoll,
Senior Sustainability Business Analyst, Nordea, Norway

Nordea's net-zero target is closely connected to the decarbonization of its customers because financed emissions represent the majority of the bank's emissions footprint. Supporting customers' transition plans and understanding how CDR can contribute to those plans are therefore important parts of its sustainability engagement. However, many corporate clients continue to strongly prioritize emissions reductions before removals, highlighting the need for clearer and more legitimate frameworks for how companies can use and make claims around CDR.

Nordea has also entered into a CDR offtake agreement involving BECCS projects in Denmark, partly to support the Nordic CDR ecosystem and partly as a learning exercise. The experience has demonstrated that signing an offtake is only the beginning: financial institutions must also develop internal knowledge around accounting, delivery, and the practical use of CDR credits. Reducing administrative and knowledge barriers remains important for broader market participation. Initiatives such as the EU Buyers Club can support this by facilitating peer learning and helping companies navigate an emerging market.

Kash Burchett,
Global Head of Carbon Removal Technologies, Climate Transition Team, Group Sustainability, HSBC HOLDINGS PLC, Hong Kong

HSBC sees carbon management, including CCS and CDR, as important both for reducing its financed emissions and for supporting investment in the broader energy transition. The bank has committed to net-zero financed emissions by 2050 and has a target of deploying up to $1 trillion by 2030 toward transition-related investments. Its carbon-management activities extend beyond conventional project finance to include equity, venture debt, and other financial solutions for emerging companies and projects.

A key financing challenge is helping CDR developers transition from equity and government grants toward debt as they scale. Early-stage developers often lack

collateral, operating track records, and positive cash flows, making conventional lending difficult. HSBC is therefore exploring new debt structures, including approaches that monetize offtake agreements. However, credible offtakes remain fundamental: banks are not yet prepared to take merchant risk on the future sale of CDR credits. Strong and predictable demand is therefore critical to unlocking debt financing and enabling CDR projects to scale.

Joel Gould,
Markets & Policy Lead, BeZero Carbon, UK

BeZero Carbon provides independent carbon ratings and risk analytics designed to reduce information asymmetries between project developers, financiers, buyers, and sellers. Such independent risk information can serve as an important piece of market infrastructure and improve project bankability by allowing market participants to better understand and price carbon-credit risks without individually recreating extensive technical due diligence.

Two important dimensions are quality risk and delivery risk. Quality ratings assess the likelihood that a credit genuinely represents the claimed a ton of CO_2 removed or avoided, while delivery-risk assessments consider whether a project will issue the quantity of credits it has promised. Engineered removals generally perform relatively well on quality, but there remains significant variation among projects. Delivery is also a material concern, with projects across the carbon market frequently issuing fewer credits than originally anticipated. Greater transparency and independent risk assessment can therefore help buyers and financiers differentiate projects, manage risk, and support capital deployment.

Discussion :

Q: How do the financial risks and financing conditions of CDR compare with CCS, and why do companies continue to prioritize emissions reductions over removals?

A: Potential CDR buyers are not necessarily companies that can use CCS themselves. Sectors such as software, food and beverage, and shipping may ultimately require CDR to address residual emissions, meaning CCS and CDR can serve different corporate needs rather than being direct alternatives.

A: The strong emphasis on “reductions before removals” may be limiting early CDR demand. Different sectors will have very different residual-emissions profiles, so uniform restrictions on the role of removals may not adequately reflect sector-specific needs, particularly in hard-to-abate sectors such as aviation.

A: In Japan, corporate decarbonization budgets are increasingly directed toward mandatory Scope 1 reductions under the emerging ETS. This may reduce the resources available for voluntary CDR purchases, highlighting the importance of creating a clearer policy position for CDR alongside emissions-reduction obligations.

Q: What are the greatest risks across the CDR market from a financing perspective?

A: Risks can broadly be divided into quality risk and quantity/delivery risk. Engineered removals should not automatically be assumed to deliver one ton of removal without risk; project quality varies considerably. Projects can also underdeliver against planned credit volumes due to technological, operational, supply-chain, regulatory, and legal risks. These risks need to be identified, priced, and actively managed rather than assumed away.

A: Even government subsidies do not eliminate technology and execution risk. Before providing debt alongside public funding, banks still need confidence that a project can successfully implement its technology and deliver the outcomes required to receive that support.

A: For financiers, risk ultimately translates into credit risk and reliable cash flow. Capture projects must be built, commissioned, and operated on schedule, while transport and storage infrastructure requires sufficient coordinated CO_2 volumes. Financing therefore depends on the performance and coordination of the entire value chain, not just an individual project.

A: Cross-chain risk remains particularly important for engineered CDR. Government backstops can help allocate risks that private parties cannot absorb, while the rapidly developing insurance market is also making technical risks more manageable. Over time, lower technology and insurance costs should further improve the economics of commercial financing.

Q: What role should governments play in mitigating risks and making CDR projects more bankable?

A: Long-term mechanisms that provide support per ton of CO_2 delivered or stored could help establish early markets. However, public support should ultimately be transitional, helping the market develop until commercial mechanisms can increasingly function independently.

A: Governments should avoid managing quality risk simply by excluding technologies or project categories. More granular approaches using technical risk assessment, insurance, and portfolio management could manage risk while preserving access to potentially lower-cost CDR solutions.

A: Government support does not guarantee delivery. Even projects receiving subsidies, contracts for difference, or auction support must still execute successfully, operate as planned, certify their removals, and ultimately deliver credits.

A: Government guarantees and backstops can significantly improve project bankability, particularly where private actors cannot absorb certain risks. Government procurement of CDR credits could also establish a baseline source of demand, reducing reliance on a limited number of voluntary corporate buyers.

A: Compliance markets and eventual government use of removals could become important sources of long-term demand. In the meantime, voluntary buyers continue to play a catalytic role, but clearer rules allowing companies to recognize CDR purchases toward their climate objectives would strengthen this market signal.

Keynote: Geographical Advantages and Constraints for Scaling CDR

Shinichirou Morimoto,
Deputy Director / CCUS Assessment Research Team Leader, Integrated Research Center for CCUS Implementation, Carbon Management Research Team Leader, Global Zero Emission Research Center, AIST, Japan

Within the Mission Innovation CDR Mission, the LCA/TEA Technical Track is working to establish common methodologies for life-cycle assessment (LCA) and techno-economic assessment (TEA) of CDR technologies. The objective is to enable transparent, evidence-based comparisons that can reduce uncertainty and support market development. Following earlier work on common LCA methodologies for direct air capture, the Technical Track is now extending this approach to enhanced rock weathering (ERW).

A key challenge is that enhanced weathering encompasses a wide range of approaches, including application to cropland, mineralization of industrial waste, and in-situ processes. Although several existing standards and guidelines are available, differences in system boundaries, functional units, allocation methods, CO_2 uptake, and leakage make consistent comparison difficult. The Technical Track is therefore working toward a methodology that can be applied across different types of enhanced weathering.

To better understand how geographical advantages and constraints affect ERW performance and economics, AIST has developed an integrated LCA/TEA evaluation tool using primary experimental data rather than relying solely on literature values. The tool incorporates factors including rock characteristics, mining, crushing and grinding, transportation distance, application rates, and crop selection. It can estimate CO_2 fixation and emissions, costs, profitability, net present value, and levelized cost of CO_2. Developing the tool required extensive primary-data collection, including sampling and analyzing rocks from multiple locations in Japan and combining these results with experimental and GIS-based transport data.

The analysis demonstrates that geography can have a major impact on both carbon-removal performance and commercial viability. Among 18 candidate sites assessed in Japan, most showed net-negative CO_2 balances, but results varied substantially by location. Hokkaido emerged as particularly favorable, with some sites showing levelized costs of approximately \$100–115 per ton of CO_2, compared with roughly \$500–1,500 per ton at less favorable locations. Only three sites in Hokkaido showed positive net present values, driven partly by significant agronomic co-benefits in addition to carbon-credit revenues.

The results indicate that ERW cannot be assessed solely on the basis of the underlying technology. Rock type, location, crop type, particle size, transportation, and other local conditions can fundamentally change project outcomes. More precisely, location-

specific assessment can therefore help identify viable projects, reduce uncertainty, and support the commercial deployment of enhanced weathering. The tool is currently available for licensing, and AIST is collaborating internationally—including with partners in the United States, Australia, and Saudi Arabia—to expand the methodology and adapt it to different geographical conditions and enhanced-weathering pathways.

Q&A

Q: Are other countries considering replicating or adapting the evaluation tool to their own geographical conditions?

A: Collaboration is already underway or being explored with the United States, Saudi Arabia, Australia, and the UK. Additional international partners are being sought to apply the methodology across a wider range of geographies and enhanced-weathering approaches.

Q: What is the biggest bottleneck for developing an enhanced weathering project in Japan—for example, transportation or rock crushing?

A: The most important factor is rock selection. CO_2-removal performance varies significantly depending on the characteristics of the rock, making access to suitable rock essential to developing a commercially viable ERW project in Japan.

Q: Is the research considering the use of naturally occurring microbes to accelerate weathering rates and potentially reduce costs?

A: Yes. Experiments involving such approaches have been conducted for several years. However, projecting performance over a 20–30-year project lifetime from only a few years of experimental data remains a limitation, and longer-term experimental evidence is needed to improve the reliability of these estimates.

Technology Enablers

Atul Sharma (Moderator),
Principal Researcher, Global Zero Emission Research Center (GZR), AIST

Akihito Yamashita,
Senior Staff Officer, CN Business Strategy Office, Energy Solution & Marine Engineering Company, Kawasaki Heavy Industries, Ltd., Japan

Kawasaki Heavy Industries is developing its Kawasaki CO_2 Capture (KCC) technology for direct air capture (DAC), building on a solid amine adsorbent originally developed for CO_2 removal in closed environments and later expanded to industrial applications. Kawasaki identifies five major challenges for large-scale DAC: the very low atmospheric concentration of CO_2, high energy requirements for regeneration, changing temperature and humidity, equipment scale-up, and long construction timelines.

KCC addresses these challenges through both adsorbent development and system design. Its amine-impregnated solid adsorbent can be regenerated using low-temperature steam at approximately 60°C, allowing low-grade waste heat from industrial sites to be utilized and reducing energy requirements. For large-scale deployment, Kawasaki is pursuing a modular approach, where capacity can be increased by adding standardized modules rather than simply enlarging individual units. A conceptual one-square-kilometer facility consisting of multiple 20,000-ton-per-year units could ultimately capture up to one million tons of CO_2 annually. Kawasaki is continuing demonstration testing and further development of adsorbents, system performance, and modularization to enable faster and more efficient commercial-scale DAC deployment.

Hanna Ojanen,
Head of Carbon Markets and Policy, Carbo Culture, Finland

Carbo Culture is scaling biochar carbon removal from pilot facilities toward industrial-scale deployment. Its approach uses residual agricultural biomass and produces several outputs simultaneously: durable carbon removal credits, biochar, and

renewable energy. The company has tested around 15 different feedstocks and currently operates a certified pilot facility in Finland with approximately 3,000 tons of capacity, while developing its first commercial facility in the Netherlands with a planned CDR capacity of approximately 24,000 tons per year.

A key enabler for scale is integration with existing industrial value chains, particularly horticulture. Greenhouses can provide biomass feedstock while purchasing renewable heat, CO_2, and biochar produced by the project. This creates a more circular system, provides an established pathway for permanent biochar storage, and diversifies project revenues beyond carbon credits. Having multiple revenue streams from energy, biochar, and CDR credits can lower credit costs and improve project bankability. For Carbo Culture, scaling therefore depends not only on reactor technology but also on developing reliable markets and value chains for the biochar and other co-products.

Edda Sif Pind Aradóttir, CEO, Carbfix, Iceland

Carbfix has developed an approach that permanently mineralizes captured CO_2 underground, accelerating a natural process so that CO_2 is transformed into stable carbonate minerals in less than two years. Following initial R&D beginning in 2007 and successful pilot injections in 2012, the technology progressed to larger-scale operations associated with geothermal energy and has accumulated more than 20 years of development and operational experience. Carbfix is now focused less on proving the core technology and more on building repeatable infrastructure for commercial deployment.

The technology dissolves CO_2 in water before injecting it into suitable subsurface rock formations, eliminating buoyancy risk and accelerating mineralization without additional chemicals. Carbfix has applied the model across geothermal operations, DAC projects with Climeworks, transported CO_2, and industrial point sources. Experience has shown that scaling requires more than technically proving permanent storage: site characterization, water management, permitting, MRV, integration with capture, and community engagement must also become repeatable and scalable. Suitable basalt and other reactive rock formations are widely distributed globally, creating significant replication potential. Japan may also offer opportunities due to its favorable geology, industrial CO_2 sources, and technical capabilities, although deployment should begin with geological validation, demonstration projects,

appropriate regulatory frameworks, and strong local partnerships.

Kel Coulson,
Director of International Policy, Oxy/Carbon Engineering, Canada

Carbon Engineering's experience with DAC demonstrates that innovation and commercial deployment need to proceed together. Its technology development progressed from research beginning in 2009 to a pilot plant, an innovation center, and ultimately Stratos in Texas. Rather than developing every component from scratch, Carbon Engineering combines established industrial processes and supply chains, using modularization where mass manufacturing provides advantages while utilizing larger equipment where economies of scale are more effective.

The innovation center is designed primarily to generate data and knowledge, allowing technologies to be tested and de-risked at relevant scale before being incorporated into commercial facilities. Meanwhile, Stratos—expected to capture more than 500,000 tons of CO_2 annually when fully operational—is already generating lessons for subsequent designs. Improvements incorporated into later phases include approximately 30% fewer air contactor units, larger and fewer reactors, and substantially shorter construction timelines. These examples demonstrate a continuous cycle of innovation, deployment, learning, and further innovation, which can reduce capital and operating costs over time. Scaling DAC globally will also require international collaboration because suitable low-carbon energy, geological storage, manufacturing capacity, and customers are distributed across different regions.

Discussion :

Q: What are the most important enablers for scaling each technology to the next level?

A: For DAC, continued improvements in adsorbent performance and system engineering are important, together with modularization that can reduce the challenges associated with equipment scale-up and construction.

A : Predictable CDR demand and revenue visibility are critical for investment decisions. Modular DAC technology could enable large-scale CO_2 removal, but broader

deployment will also require supply chain development, supportive policies, and infrastructure.

A: Existing policy and subsidy frameworks should be expanded to include a broader portfolio of permanent CDR technologies, including biochar. Different CDR approaches should be treated as complementary rather than competing solutions, as a portfolio will be needed to achieve the required scale.

A: Developers need clear, long-term policy guidance on targets, incentives, permitting, compliance, and MRV requirements. Development timelines across capture, transport, and storage must also be coordinated, while strong community engagement is critical for securing local trust and enabling projects to proceed.

A: Demand needs to be designed with future megaton-scale deployment in mind. Large facilities may need to serve multiple markets—including voluntary markets, compliance schemes, and CO_2 utilization—so market and registry systems should provide sufficient flexibility for projects to access different sources of demand.

Q: How should developers manage the significant upfront financial risk involved in scaling from pilot projects to commercial facilities?

A: Financing should combine multiple sources, including government support, carbon-credit pre-purchases, long-term demand signals, and private financing. As projects expand internationally, partnerships with organizations that understand local markets will also become increasingly important.

A: Scale-up inevitably involves risk, so one approach is to increase project size in manageable increments rather than making excessively large jumps. Gradual scaling—such as increasing capacity by roughly a factor of ten at each stage—can help contain risk while building operational experience. Government support has also been important for enabling larger projects.

A: Developing multiple revenue streams can strengthen project finance. For biochar projects, revenues from energy, biochar, and CDR credits can reduce dependence on a single market. CDR offtake contracts also need to mature and become better aligned with land, energy, product-offtake, and other agreements required for project financing.

A: The deployment of DAC requires a complete CO_2 value chain, not just capture equipment. While government support is needed in the early stages, long-term growth will depend on sustainable financing through private investment and project finance.

A: Government and community support are also important for reducing the risks associated with technology scale-up and enabling projects to move toward commercial deployment.

Breakout Discussions: Strategic Dimensions of CDR Scale-up

Speakers and audience were divided into three breakouts listed below to discuss key enablers for rapid CDR scale-up.

•**Breakout A:** Demand Signals, Market Confidence, and Implications for CDR Developers

•**Breakout B:** Demand Signals, Market Confidence, and Implications for CDR Buyers

•**Breakout C:** Technology Readiness, Demonstration, and Implications for CDR Scale-up

Breakout A: Demand Signals, Market Confidence, and Implications for CDR Developers

Juho Lipponen (Group Facilitator), Coordinator and Acting Director, MI CDR Mission

The discussion identified five key enablers for CDR developers. First, developers need a clear monetization mechanism for each ton of carbon removed, supported by standardized and functioning markets. Without a credible pathway to monetize removals, developers will struggle to advance projects. Second, stronger demand creation is required from both the public and private sectors, potentially supported by more standardized contracting structures.

Third, industrial integration can help CDR projects scale by embedding carbon removal within existing industries and value chains rather than developing projects in isolation. Fourth, developers need better access to finance, including more sophisticated financing mechanisms appropriate for emerging CDR projects. Finally, policy frameworks should remain flexible and allow for learning by doing. Rather than prescribing a single pathway, governments could establish clear objectives while allowing technologies and business models to evolve toward those goals.

Hanna Ojanen (Group Facilitator), Head of Carbon Markets and Policy, Carbo Culture, Finland

The second table of breakout A emphasized the importance of long-term demand certainty, particularly through compliance markets. Recent volatility in voluntary purchasing highlighted the risks of relying too heavily on a small number of corporate buyers. Compliance markets could provide greater investment security not only for first-of-a-kind projects but also for the subsequent projects required to achieve meaningful scale. At the same time, the voluntary carbon market remains important as a way for companies to demonstrate early commitment and help establish pathways that could later feed into compliance markets.

The group also saw positive signs in the way buyers are currently experimenting with different CDR approaches, learning from actual contracts and comparing initial assumptions with project outcomes. This exploratory phase can improve buyer strategies and contribute to broader market maturity. Finally, the group stressed the importance of maintaining a portfolio of CDR solutions. Every method has advantages and disadvantages, and achieving the required scale will require continued investment across multiple CDR pathways rather than relying on a single technology.

Breakout B: Demand Signals, Market Confidence, and Implications for CDR Buyers

Marianne Bruvoll (Group Facilitator), Senior Sustainability Business Analyst, Nordea, Norway

Group B focused on mechanisms for creating and sustaining CDR demand. A central message was that buyers need greater stability and clarity. Regulatory frameworks

such as the EU Carbon Removals and Carbon Farming (CRCF) framework can provide an important reference point, while clearer corporate guidance is needed to help companies understand which credits to purchase, how to account for them, and how they can be reported. A continuing challenge is that standards and frameworks are evolving simultaneously, creating uncertainty for buyers.

This group discussed the EU Buyers Club as a mechanism for creating early demand before 2030, ahead of the period when other corporate frameworks are expected to drive stronger demand. The initiative can also facilitate shared learning: participating companies conduct their own due diligence but exchange information on project risks, mitigation measures, and eligibility criteria. Transparency around how such mechanisms operate will be important to ensure that they send credible signals to the market.

Compliance markets and carbon pricing could provide additional price anchors and stability for CDR. The group also noted the importance of sector-level participation: buyers may be more willing to enter the market when competitors and peers in the same industry participate as well. Coordinated engagement within sectors could therefore strengthen buyer confidence and generate clearer demand signals for developers.

Breakout C: Technology Readiness, Demonstration, and Implications for CDR Scale-up

Atul Sharma (Group Facilitator), Principal Researcher, Global Zero Emission Research Center (GZR), AIST

Group C discussed the technical and economic challenges of moving CDR technologies from lower TRLs to larger-scale deployment. One major issue is reliability: technology that performs successfully at small scale may encounter new operational problems when scaled up. Field demonstrations and reference projects are therefore important for validating performance and giving future developers, investors, and financiers confidence. Innovation should also be understood as an iterative process, with deployment generating lessons that feed back into further technology development.

This group also discussed challenges around project commitment and availability of specialized talent. Participants had differing views on whether the sector currently faces a significant talent shortage, but the ability to move projects from low to high TRLs requires appropriate technical expertise and project-development capabilities.

Another key topic was the amount of operational validation and monitoring data required to assess economic risk. Changing MRV requirements can create uncertainty, particularly when financiers must assess projects over long investment periods. From a banking perspective, the central concern is ultimately whether projects can generate sufficient and reliable returns rather than any single technical metric in isolation. The group also highlighted the potential importance of combining MRV with life-cycle assessment (LCA) and other performance evidence when evaluating novel CDR pathways.

Day 2

Keynote: Accelerating Materials Innovation for Clean Energy

Christopher Toews,
Director, Energy Innovation Policy, Office of Energy Research and Development, Natural Resources Canada, Canada

Advanced materials are increasingly important across the energy transition, including carbon capture and removal, batteries, hydrogen, semiconductors, and renewable energy. As countries seek to strengthen their competitiveness and industrial leadership in these areas, accelerating the traditional materials-development cycle—from discovery and manufacturing optimization to technology integration and market deployment—has become increasingly important. A key tool for achieving this acceleration is the self-driving laboratory, which integrates artificial intelligence, high-performance computing, robotics, automation, experimental databases, and human scientific expertise into a closed-loop materials discovery platform.

In a self-driving lab, AI and computational tools explore a much wider materials-design space than conventional trial-and-error approaches. Robotic systems then manufacture and experimentally characterize candidate materials, with the resulting data fed back into AI models to inform the next iteration. Importantly, human scientific

judgment remains central to interpreting inputs and outputs. This approach can substantially accelerate materials discovery and optimization for applications including batteries, hydrogen, and carbon management.

The Mission Innovation Materials for Energy (M4E) initiative, established in 2018 and co-led by Canada, Italy, and the European Commission, aims to expand and democratize access to these materials-acceleration approaches. Through international research collaboration, knowledge sharing, workshops, joint publications, and materials acceleration centers, the initiative has helped develop a global ecosystem around self-driving laboratories. Canada has invested significantly in this area, including more than $500 million across multiple initiatives since 2018, and has established dedicated facilities designed for flexible, modular, closed-loop materials research.

For carbon management specifically, AI-enabled materials acceleration can help identify and optimize materials that interact effectively with CO_2. Computational models can predict promising materials, automated systems can manufacture and test them, and experimental results can continuously improve subsequent designs. Canadian research programs are already applying AI and machine learning to capture materials for industrial CCS, DAC and BECCS, CO_2 conversion catalysts, and geographic mapping of carbon-management opportunities based on factors such as energy availability, emission sources, and storage potential. International collaboration through M4E can further accelerate the development and deployment of these technologies.

Keynote: Materials Innovation to Scalable Carbon Removal

Dai Kataoka,
Managing Director & COO, Atomis Inc., Japan

The central challenge for carbon removal is increasingly shifting from innovation to scale. Advanced materials can improve carbon capture, separation, and storage, but the economics of CDR ultimately depend on the entire value chain—from capture through transportation, utilization, or permanent storage. Atomis Inc. is developing advanced porous materials known as metal-organic frameworks (MOFs), whose molecular properties can be precisely engineered by changing their metal ions and organic linkers. This ability to control molecular interactions creates opportunities to

improve separation and storage processes while reducing energy use and system complexity.

One application is industrial carbon capture using MOFs in pressure swing adsorption (PSA) systems. Conventional capture processes can require pretreatment because flue gases contain water and other impurities. Atomis Inc. is developing MOFs that maintain CO_2 selectivity in the presence of water, potentially simplifying equipment and reducing energy consumption. Following demonstration at approximately 30 kg-CO_2/day, the company is preparing for ton-scale testing. Atomis Inc. has also applied MOFs to refrigerant separation, including commercial implementation in Europe, and is exploring MOF-based natural-gas storage combined with digital technologies. These examples demonstrate the wider potential of advanced porous materials for controlling the separation, storage, and distribution of molecules.

However, discovering a high-performing material is fundamentally different from commercializing it. More than 100,000 MOF structures have been reported, but only a small number have reached real-world applications. Atomis Inc. therefore integrates AI-assisted materials design, validation, manufacturing, and deployment within a single platform. Its pilot manufacturing capacity is currently around 20 tons per year, with expansion toward 200 tons per year being prepared.

At commercial scale, success depends on reproducible manufacturing, cost, safety, regulatory approval, engineering integration, and customer adoption, not simply laboratory performance. The so-called “valley of death” between research and commercialization is therefore not only a funding problem but also a coordination challenge involving technology, capital, regulation, manufacturing, and market demand. Materials innovation creates possibilities, but meaningful climate impact only occurs when technologies can be manufactured reliably and deployed at scale.

Q&A

Q: How should the industry balance continued materials innovation with scaling technologies that are already available?

A: Economic viability is the key consideration. MOFs offer enormous technical possibilities, but material costs must be reduced substantially before many applications can scale commercially. Cost reduction and manufacturing scale-up therefore need to progress alongside continued innovation.

Q: What CO_2 recovery rates can MOF-based capture achieve?

A: Recovery rates above 90% are achievable, but there is a trade-off between recovery rate and CO_2 purity. Increasing recovery can reduce product purity, potentially below 95%, so the system must be optimized according to application requirements.

Q: What are the principal challenges associated with MOFs for carbon capture?

A: Durability is a major issue. Some MOFs have demonstrated resistance to water and other substances and could potentially operate for five to ten years, but longer-term testing and data are still required.

Q: Are there environmental or human-health concerns associated with large-scale MOF deployment?

A: Safety needs to be supported by appropriate data, but MOFs can be designed using relatively benign metals such as calcium, magnesium, aluminum, or zinc and suitable organic linkers, while avoiding more problematic materials.

Q: Would deploying MOFs require major modifications to existing carbon-capture systems?

A: Not necessarily. MOFs can be used with conventional systems such as PSA, although the material may need to be formed into appropriate structures, such as pellets or honeycomb configurations, depending on the application.

Q: Has the technology already been tested at pilot scale?

A: Atomis Inc. has completed smaller-scale demonstrations and is currently preparing ton-scale demonstration testing for carbon-capture applications.

Q: Why can a material that performs well in laboratory research become difficult to deploy at larger scale?

A: Laboratory synthesis can rely on conditions—such as toxic solvents, high pressures, or expensive processes—that are unsuitable for industrial production. Materials may therefore have excellent scientific performance but still require substantial manufacturing and engineering innovation before it becomes commercially scalable.

Keynote: The 2027 IPCC CCS & CDR Methodology Report - state of play and implications for CDR deployment

Takao Nakagaki,
Professor, Faculty of Science and Engineering, Waseda University / 2027 IPCC CDR/CCUS methodology report coordinating lead author, Japan

The upcoming 2027 IPCC CDR/CCUS Methodology Report is intended to address important gaps in existing national greenhouse gas inventory guidance created by technological innovation since the 2006 IPCC Guidelines. Emerging approaches such as direct air capture, biochar, enhanced rock weathering, and new carbon-utilization pathways are not adequately covered by existing methodologies. The new report will therefore provide standardized methodologies that allow countries to incorporate a broader range of CDR and CCUS activities into their national greenhouse gas inventories.

The report will consist of six volumes. While Volumes 1–5 provide targeted updates to existing guidance across sectors such as energy, industrial processes, agriculture and land use, and waste, Volume 6 introduces a dedicated framework for CDR and CCUS. Importantly, the methodology report is intended as practical guidance for national greenhouse gas inventory compilers rather than as a policy prescription or an assessment of which technologies governments should pursue. It also differs fundamentally from project-level carbon-credit accounting: national inventories seek comprehensive and internally consistent accounting within national jurisdictions, whereas crediting frameworks evaluate individual projects and require project-specific demonstration of net-negative outcomes.

The emerging framework considers the full CO_2 value chain, including capture from combustion and process gases, direct air capture and other sources, transportation, utilization, and geological or other long-term storage. The accounting framework is intended to maintain mathematical consistency regardless of the eventual fate of captured CO_2 and to distinguish between fossil-derived CO_2 and CO_2 originating from biomass or the atmosphere. The report remains under development, with expert and government reviews continuing ahead of planned approval in December 2027 in Yokohama, Japan.

One area that remains challenging is marine CDR. Certain approaches involving enhancement of water bodies are not currently included in the methodology, while areas such as seagrass, ocean capture, and blue carbon receive treatment. Key difficulties include identifying and tracking dissolved inorganic carbon, determining jurisdiction once carbon moves through rivers and oceans, and assessing potential ecosystem impacts. At the same time, the presentation emphasized the importance of continuing research rather than allowing uncertainty to prevent progress. International consensus, model-based methodologies, monitoring and assurance systems, and appropriate incentives will be necessary if marine CDR is to be incorporated more systematically in the future.

The presentation also highlighted ongoing work on advanced enhanced rock weathering (ERW) using materials such as mine tailings, dust, and ultramafic rocks. Different deployment configurations—including applications on farmland and other open environments as well as closed systems—offer different trade-offs across cost, removal speed, carbon certainty, and energy requirements. No single approach performs optimally across every metric, reinforcing the importance of evaluating CDR technologies across multiple performance dimensions rather than relying on one indicator alone. In other words, since there is no flawless CDR technology, each should complement the others.

Finally, accelerating CDR deployment requires more than methodologies and technical performance. Demonstration projects that create compelling and understandable examples can help build public and stakeholder support, particularly among younger researchers and emerging innovators. One example presented integrates waste heat from data centers with direct air capture: recovered heat is used to regenerate a carbon-capture solvent, the resulting CO_2 is mineralized using magnesium-rich rocks, and the resulting mineralized material can be used in asphalt pavement. Such integrated value-chain examples can demonstrate how different

technologies and industrial resources can be combined to create practical CDR pathways.

Building Trust at Scale: Standards, Market infrastructure, and Risk Management

Morgan Edwards (Moderator),
Executive Team, State of Carbon Dioxide Removal

Delia Meth-Cohn,
Co-Founder, Rethinking Removals, UK

The CDR market needs a broader ecosystem of standards to build trust and unlock demand at scale. Existing standards can broadly be divided into supply-side standards, which determine whether a carbon removal is effective and meets appropriate quality criteria, and demand-side standards, which govern how companies can use removals within their climate strategies and accounting. While significant progress has been made on the supply side, removals are still insufficiently integrated into corporate standards, creating uncertainty for companies about why they should purchase CDR, how purchases can be recognized, and what claims can be made. This lack of clarity remains an important barrier to corporate demand.

This is beginning to change. Emerging SBTi requirements are expected to require companies to begin taking actions on removals ahead of net zero, while the ISO net-zero standard and evolving carbon-accounting frameworks could provide additional pathways for corporate use of CDR. However, carbon removal ultimately needs to become part of normal corporate operations and decarbonization strategies, including through integration into industrial value chains, rather than remaining a separate or unusual activity. The current standards landscape represents only the beginning of the market infrastructure required. Scaling CDR will require a much richer ecosystem of standards, accounting approaches, financial instruments, and other mechanisms, with today's decisions designed around what the market will need in the future.

Antti Vihavainen,
Vice Chairman, Puro.earth, Finland

As the CDR market expands, standardized quality assurance can substantially reduce the burden of buyer due diligence. With hundreds of buyers and suppliers today—and potentially tens of thousands of buyers and thousands of suppliers in the future—it would be impractical for every buyer to independently assess every project. Carbon-removal standards and registries can therefore act as trusted intermediaries: buyers conduct due diligence on the standard itself, while the standard assesses whether individual suppliers meet defined quality requirements.

Standards and ratings agencies play distinct but complementary roles. Puro.earth essentially provides a binary quality threshold, determining whether a removal activity meets requirements for real, measurable, durable carbon removal and avoids issues such as double counting. Ratings agencies, by contrast, provide comparative assessments of risks among projects. Standards must also evolve over time as scientific knowledge and practical experience improve, allowing the quality threshold to be raised progressively. Methodology development therefore requires collaboration among scientists, practitioners, independent experts, and broader frameworks such as CRCF and CORSIA. For neutralization claims, high quality is essential, which justifies a cautious approach to approving new methodologies.

Joel Gould,
Markets & Policy Lead, BeZero Carbon, UK

Independent carbon ratings can help scale the CDR market by giving buyers a simple and comparable indication of project risk, reducing the need for every buyer to maintain extensive internal due-diligence capabilities. Ratings are not intended simply to criticize projects; rather, they provide information that enables buyers to differentiate projects, price risks, and manage portfolios. Engineered CDR projects generally perform relatively well in BeZero's assessments, but there is still meaningful variation even within individual technology categories such as biochar.

Ratings assess factors including additionality, carbon accounting, and permanence. Differences in financial additionality, LCA transparency, operational performance, leakage, feedstock use, and biochar stability can therefore result in materially different ratings even for superficially similar projects. Ratings are increasingly being used in corporate procurement criteria, RFPs, and sustainability reporting, functioning as both decision-making and communication tools. Looking ahead, regulation of ratings

agencies, including emerging EU requirements around transparency and conflicts of interest—could further strengthen trust. Ratings may also become part of a broader, more professionalized carbon-market risk-management ecosystem alongside standards, insurance, financial intermediaries, and government procurement frameworks.

Discussion :

Q: What should the standards and market ecosystem look like by 2035 if CDR successfully scales?

A: Corporate rules should be much clearer about how much CDR companies need, when they should begin purchasing, what claims they can make, and how durability should be addressed. As CDR becomes increasingly integrated into existing industries, concepts such as additionality may also need to evolve, and revenues will likely come from multiple business activities rather than carbon credits alone.

A: Supply growth must be accompanied by a much broader buyer base. Low-friction mechanisms such as standardized contracts, baskets, and ready-made CDR portfolios could enable large numbers of companies to participate without conducting extensive individual transactions and due diligence.

A: The market should move toward a more open framework in which different CDR solutions can compete while risks are managed professionally. Ratings, standards, insurance, intermediaries, and financiers can provide the risk-management architecture needed to support a broader range of technologies without relying excessively on prescriptive restrictions.

Q: By 2035, should there be fewer standards, or can multiple standards continue to coexist?

A: The standards ecosystem may not necessarily become smaller, but it should become much more harmonized. Different standards and organizations can continue to perform specialized functions, provided that requirements are aligned and fragmentation does not create unnecessary complexity or slow market development.

Q: What actions are most important in the next few years to enable the CDR market envisioned for 2035?

A: The use cases for carbon-removal credits need to be clarified, particularly within major regulatory frameworks such as the European Union, so companies understand how removals can be used.

A: A near-term priority is achieving broad agreement that removals should be incorporated into relevant corporate standards starting now rather than only at net zero. Once that principle is established, detailed rules can be developed over the following years.

A: Upcoming consultations on issues such as permanence and durability provide an important opportunity to shape future CDR rules. The CDR community should provide evidence on how different removal pathways and their risks can be incorporated rather than unnecessarily excluding technologies through rigid categories.

Q: How can companies and other stakeholders participate in the development of these standards?

A: Standards organizations increasingly seek direct corporate input through public consultations, pilot programs, and stakeholder feedback. Companies can participate by following consultation processes, submitting comments, joining pilots, and engaging directly with organizations developing the standards.

National Policies and Activities

Kash Burchett (Moderator), Global Head of Carbon Removal Technologies, the Climate Transition Team, in Group Sustainability, HSBC

Rufaydah H Alyamani, International Initiatives Team Lead, Ministry of Energy, Kingdom of Saudi Arabia

Saudi Arabia is pursuing carbon management as part of its ambition to achieve net

zero by 2060, guided by the Circular Carbon Economy framework, which seeks to balance emissions management with energy security and economic development. Domestically, the Kingdom is investing across the CCUS value chain, including capture, utilization, transportation, and permanent storage. Major initiatives include an eastern-region CCUS hub expected to reach approximately 9 million tons per year by 2028, as well as plans for a carbon capture and utilization hub in the western region. The objective is increasingly to move from individual projects toward larger, integrated carbon-management infrastructure.

Saudi Arabia is also exploring a range of CDR and CO_2 utilization technologies. DAC has been tested under different climatic conditions, including the arid environment of Riyadh and conditions in the eastern region, to understand how technologies perform locally. Other examples include CO_2 mineralization in concrete and captured CO_2 for industrial and food-grade applications. Policy measures are being developed alongside these technologies to create demand for captured CO_2 and encourage its productive use. Overall, Saudi Arabia views carbon management as a full ecosystem involving technology, infrastructure, utilization, and policy, rather than focusing on a single technology pathway.

International cooperation represents the second pillar of the Kingdom's approach. Saudi Arabia participates in the Clean Energy Ministerial, Mission Innovation's CDR Mission, the Carbon Management Challenge, and initiatives such as the Smart CDR Competition. These platforms are intended to facilitate knowledge sharing, policy and regulatory cooperation, innovation, and development of solutions for challenges such as MRV. The broader objective is to strengthen international collaboration and establish an enabling environment and positive narrative for scaling a diverse portfolio of carbon-management solutions.

Keiji Hisata,
Senior Negotiator for Climate Change Global Environmental Affairs Office GX Policy Group, Ministry of Economy, Trade and Industry, Japan

Japan's Joint Crediting Mechanism (JCM) is a bilateral framework under Article 6 of the Paris Agreement designed to facilitate emission-reduction projects between Japan and partner countries. Japanese and local companies jointly develop projects, with resulting credits shared according to their respective contributions. The JCM has

operated for more than a decade and currently covers 32 partner countries and more than 300 projects, providing incentives for innovative decarbonization technologies and activities that might otherwise be difficult to implement.

METI supports JCM projects at different development stages, including feasibility studies and demonstration projects. Demonstration support can cover project costs over several years, while earlier-stage programs help assess project viability. Japan and Indonesia have also developed specific CCS guidelines under the JCM to address the technical and legal complexity of CCS projects, and Japan is examining whether this approach can be extended to other partner countries.

On the demand side, Japan launched its GX ETS in 2026 following a three-year trial period. Companies emitting more than 100,000 tons annually are covered, representing approximately 60% of Japan's emissions, and JCM credits can be used within the system. This creates a connection between international project development, carbon credits, and Japan's domestic carbon-pricing framework.

Christopher Toews,
Director, Energy Innovation Policy, Office of Energy Research and Development, Natural Resources Canada

Canada's federal approach to CCUS and CDR is organized around its Carbon Management Strategy, a technology-neutral umbrella framework intended to provide greater coherence and long-term direction to the sector. Federal support combines several policy instruments across the innovation and deployment value chain. The foundation is carbon pricing, implemented through different provincial systems operating under a common federal benchmark. Investment tax credits provide another important instrument, with both DAC and BECCS eligible under the CCUS tax credit.

Canada also uses strategic finance through institutions such as the Canada Growth Fund, including potential offtake agreements and contracts for difference, while federal R&D programs support earlier-stage development. Natural Resources Canada's approximately CAD 319 million CCUS and CDR RD&D program supports activities including FEED studies, while a pilot CDR procurement program is testing government purchasing as an additional demand-side mechanism. Canada has also joined the Advanced Carbon Removal Coalition, providing another model for public-private collaboration.

An important lesson from Canada's experience is that federal incentives can also encourage action at the provincial level. Eligibility conditions attached to investment tax credits have helped motivate provinces to establish CO_2 storage regulations, permitting systems, and safety standards. Canada is therefore combining carbon pricing, fiscal incentives, strategic finance, procurement, R&D support, and regulatory development to support the emerging CDR sector.

Belladonna Maulianda,
Executive Director, Indonesia CCS Center

Indonesia is rapidly developing the regulatory and market infrastructure for CCS and CDR. The Indonesia CCS Center supports this process through policy advocacy, regulatory development, market activation, international partnerships, stakeholder matchmaking, and capacity building. Recent developments include Presidential Regulation No. 110 on carbon economic pricing, the creation of a national carbon-unit registry, and development of a roadmap covering both compliance and voluntary carbon markets. Indonesia is also seeking compatibility with internationally recognized carbon standards and mechanisms.

A broader set of regulations is being established around CCS, carbon storage, licensing, waste-to-energy, and carbon registries, alongside the adoption of relevant ISO standards. International cooperation is another important component, including Article 6.2 cooperation with Singapore, cross-border CCS cooperation with Singapore and South Korea, and JCM cooperation with Japan.

Indonesia sees its large geological storage potential and emerging CCS infrastructure as potential foundations for future CDR deployment. Approximately 19 CCS projects are under development, including projects involving Japanese partners, while opportunities are being explored for BECCS, DAC, waste-to-energy with CCS, and nature-based removals. Indonesia's strategy is therefore to first establish infrastructure, regulations, and commercial CCS projects that can subsequently enable a broader portfolio of CDR pathways.

Discussion :

Q: How do your governments view the role of CCS and CDR within their broader energy, climate, and economic strategies?

A: Saudi Arabia considers carbon management a central component of its Circular Carbon Economy and its pathway toward net zero. Deployment is expected to involve public-private partnerships, combining government support with private-sector innovation and investment.

A: Japan takes a technology-neutral approach, focusing on overall GHG reductions rather than prioritizing individual technologies. CDR is viewed as one of several technologies with significant potential to contribute to future emissions reductions, including through the JCM.

A: Canada increasingly views carbon management through both climate and economic competitiveness lenses. Alongside achieving net zero by 2050, CCUS and CDR are seen as areas where Canada could generate investment, commercial opportunities, and employment.

A: Indonesia's approach is more market-driven, relying substantially on international carbon markets, Article 6.2, the JCM, and potential cross-border CO_2 transport. CCS and CDR are also viewed as emerging industries that could benefit from incentives such as tax holidays and import-tax exemptions, although viable business models are still being developed.

Q: What are the major challenges to translating government support into actual CCS and CDR deployment?

A: In Canada, multiple government institutions and financial organizations operate under different mandates, making coordination challenging, particularly for technologies with significant technical and commercial risk. Greater offtake support may also be needed, while investment tax credits can be difficult to update quickly enough to reflect rapidly evolving CDR technologies and business models.

A: In Japan, a key challenge is the substantial gap between current CDR costs and carbon prices under the GX ETS. Scaling CDR may therefore require carbon-removal credits to generate value beyond simply substituting for conventional emissions

allowances.

A: Indonesia's immediate priority is moving from regulation to operational projects. Successful flagship projects would demonstrate feasibility and build confidence, while government can support deployment by streamlining permitting and other administrative requirements.

A: Saudi Arabia needs to determine how technologies developed elsewhere perform under local climatic and industrial conditions. Factors such as heat, humidity, industrial integration, and commercial viability must be tested, while longer-term targets beyond 2030 could provide stronger momentum for deployment.

Q: Could Canada or Saudi Arabia adopt an international carbon-credit approach similar to Japan's JCM and Article 6.2 framework?

A: Canada is actively considering international credit transfers, with stakeholders advocating for greater engagement. Potential benefits include attracting international investment, while a key concern is ensuring that transferred reductions do not undermine Canada's ability to meet its own domestic emissions targets. Canada is studying international experiences, including Japan's JCM.

A: Saudi Arabia is already developing voluntary carbon-market activity, but the presentation did not identify a specific plan for a JCM-like cross-border mechanism. Any future approach would need to align with the Circular Carbon Economy while supporting economic development and energy security.

Q: How does Article 6 relate to Japan's JCM and GX ETS?

A: Japan developed the JCM as a bilateral mechanism under Article 6.2, drawing on experience with the more centralized UN crediting architecture under the Kyoto Protocol. The bilateral model provides greater flexibility for project development while maintaining environmental-integrity requirements. JCM credits can also be used within Japan's GX ETS, although their use is currently subject to a limit as a safeguard during the system's early phase. Future treatment will depend partly on market demand and carbon prices as GX ETS develops.

MI CDR "SMART CDR Competition": The Journey of a Japanese Start-up

Rufaydah H Alyamani,
International Initiatives Team Lead, Ministry of Energy, Kingdom of Saudi Arabia

The Smart CDR Competition is a flagship activity under Mission Innovation's CDR Mission that we launched to bring the next generation into solving real-world carbon dioxide removal challenges. Through the competition, we invite university students from around the world to think creatively about current CDR issues and connect them with expertise from academia, government, and industry.

Since launching the competition in June 2024, we have received participation from 78 student teams across 24 countries, supported by 22 expert reviewers and multiple international sponsors and partners. Three winning teams were selected in early 2025. Through this initiative, we aim not only to generate innovative CDR solutions, but also to engage young researchers and innovators and encourage them to become part of the future CDR ecosystem.

Ryoya Sato,
Second-year master's student, Graduate School of Engineering, Hokkaido University, CDR^2 (CDR squared), Japan

My research explores how acid mine drainage can be turned from an environmental liability into an opportunity for carbon removal. Acid mine drainage is highly acidic water generated at mining sites and can contain harmful contaminants such as iron and arsenic, creating a long-term wastewater-management burden. My approach applies enhanced weathering to this acidic water by adding suitable minerals, accelerating their dissolution and ultimately enhancing CO_2 removal. At the same time, the process can increase the pH of the wastewater and reduce harmful contaminants, creating important environmental co-benefits alongside CDR.

Participating in the Smart CDR Competition was also an important turning point for me personally. Preparing for and winning the competition gave me confidence and encouraged me to think beyond academic research toward commercialization. After

the competition, I received advice from the judges on how the technology could succeed in the market, secured a Japanese government research grant, and conducted experiments at a mine-drainage site using an automated system I developed, achieving promising results. My goal is to eventually establish a startup and become a carbon-credit supplier using this technology, turning my research into a practical CDR business.

From Insights to Action: Building CDR Roadmaps

Delia Meth-Cohn, Co-Founder, Rethinking Removals

Andrew Lenton, MI CDR Co-lead, Director CarbonLock, CSIRO, Australia

Australia developed its CDR roadmap to better understand how the country's substantial natural and technical resources—including renewable energy, minerals, oceans, and geological storage—could translate into practical CDR opportunities. The roadmap examines which technologies are suitable for Australia, where they could be deployed at a regional level, their current and future costs and capacities, key technology and research gaps, and the enabling environment required for deployment.

Importantly, the roadmap is not viewed simply as a final document, but also as a process for building partnerships and coordination. CSIRO therefore engaged federal and state governments, government agencies, researchers, industry, and other stakeholders through steering committees and cross-government working groups. Although CDR technologies will continue to evolve and parts of the roadmap will inevitably become outdated, the relationships, trust, and shared understanding created through the roadmapping process can provide a lasting foundation for future CDR development.

Koji Kojima,
Japan CDR Coalition, Advisory Associate, Future Co-Creation Group, Customer Relations Division Mitsubishi Research Institute, Inc., Japan

The Japan CDR Coalition developed its CDR Industrialization Roadmap primarily from

a business and industry perspective. The roadmap starts from the premise that CDR will be essential for counterbalancing residual emissions on the pathway to carbon neutrality and seeks to translate this need into concrete actions for businesses and policymakers. The Coalition, established approximately one year earlier, has grown to 91 members spanning major corporations and startups across multiple sectors, with market development and sustainable CDR industrialization as key objectives.

The roadmap addresses two major challenges: establishing a practical pathway for using CDR to address residual emissions and building a cross-sector industrial ecosystem capable of turning CDR into a growing business opportunity. It sets out three broad phases, beginning with a preparation phase focused on establishing the foundations for industrialization, followed by introduction and expansion during the 2030s, and ultimately the development of stable and cost-effective CDR supply chains toward net zero. During the initial phase, creating clear demand signals, accelerating project formation and commercialization, and developing appropriate CDR rules are particularly important. The roadmap is intended as a starting point and a common strategic compass that will continue to evolve through domestic and international stakeholder input.

Jeroen Schuppers, Senior Expert, European Commission

The European Commission is developing its CDR approach through two parallel tracks: research and innovation, and an enabling framework for market creation. EU modeling indicates that significant carbon removal will be required to achieve climate neutrality by 2050, including contributions from DACCS and BioCCS. Building on more than two decades of support for CCUS research, the EU is therefore increasingly extending its activities toward CDR technologies.

On the market side, the EU has established the Carbon Removals and Carbon Farming (CRCF) framework to certify permanent removals and has created an EU Buyers Club to connect buyers with projects capable of supplying certified removals. The Commission is also working to integrate permanent domestic carbon removals into the EU ETS framework. These research, innovation, and market-development measures need to be coordinated through a roadmap that defines targets and milestones and addresses Europe's fragmented stakeholder landscape. The roadmap process is therefore intended to establish shared priorities and joint ownership among the Commission, Member States, industry, and the research community.

Alexander Makela,
Chief Policy Officer, Carbon Gap

A credible CDR roadmap should begin by assessing a jurisdiction's technical potential and natural endowments, including available resources, infrastructure, existing value chains, land, biomass, energy, and storage. It should then account realistically for constraints and trade-offs between different CDR approaches and develop a portfolio reflecting different levels of technological readiness. However, identifying technical potential alone is insufficient: a roadmap also needs to explain how actual demand will be created and who will ultimately pay for removals, otherwise projects will remain difficult to finance.

Roadmaps should also account for existing and cross-border value chains—for example, situations where CO_2 capture occurs in one country, but geological storage is located in another. The road mapping process itself can create alignment among industry, national and local governments, communities, and other stakeholders, but the roadmap must remain actionable and regularly reviewed rather than becoming a static document. Carbon Gap is complementing this work through a policy levers library covering around 160 policy instruments and approximately 500 international case studies, designed to help translate broad roadmap ambitions into concrete policy actions.

Discussion：
Q: How should stakeholders be involved in developing a CDR roadmap?

A: The EU uses a structured process involving the Commission, Member States, industry, and research organizations. Stakeholders first establish a shared vision and strategic research agenda, followed by implementation and investment commitments that clarify what should be done, by whom, and with what resources.

A: Australia combined broad national and international consultation with a smaller steering group responsible for developing the roadmap. Regular engagement with the wider stakeholder community helped ensure that the final roadmap remained focused, useful, and broadly supported.

A: In Japan, stakeholder engagement also has an important educational role. Awareness of CDR remains relatively limited among some business leaders, policymakers, and consumers, so the roadmapping process can help build a common understanding of CDR, carbon credits, and the role of removals in achieving net zero.

Q: Does it matter whether a CDR roadmap is led by government, industry, or another organization?

A: The appropriate leader depends on the purpose and intended audience. An industry-led roadmap can demonstrate that a credible market is emerging and communicate concrete needs to government, while other roadmaps may primarily address data or knowledge gaps. The starting point should therefore be clarity about what the roadmap is intended to achieve and who needs to use it.

Q: At what stage of CDR market development should a roadmap be created?

A: There is no single ideal stage. In countries where CDR is still at an early stage, a roadmap can serve as a **conversation starter**; in more developed markets, it can help coordinate existing activities or provide industry with evidence for policy discussions. Its role should therefore reflect the maturity and specific needs of the jurisdiction.

Q: How should community engagement and regional planning be incorporated into CDR roadmaps?

A: Roadmaps can identify regional CDR opportunities without prematurely designating specific communities for development. This allows local communities—including First Nations communities—to discuss which technologies they may want, what employment opportunities could emerge, and what skills would be required.

A: Community engagement is particularly important for CO_2 storage, which has historically faced greater public acceptance challenges than capture itself. Visible demonstration projects and proactive public-information campaigns can help communities understand both the technology and its potential benefits.

Q: For a country beginning to develop a CDR roadmap, should the process start with industry or government?

A: Japan's industry-led approach deliberately began with a relatively focused roadmap

to create an initial market signal and starting point for wider discussion, rather than waiting until every difficult question had been resolved.

A: Public-sector involvement is necessary because emerging CDR technologies face market failures that industry cannot solve through technology development alone. Government can provide enabling frameworks and early support while industry contributes technical and commercial expertise.

A: Roadmaps should become increasingly concrete by identifying near-term technologies, timelines, capital requirements, and opportunities to integrate CDR into existing industries. R&D, MRV, demand creation, infrastructure, and storage should progress in parallel, rather than sequentially.

Q: How can CDR roadmaps remain relevant as technologies and markets evolve rapidly?

A: Rather than repeatedly producing entirely new roadmaps, updates can be made incrementally when meaningful new information or stakeholder demand emerges. Maintaining the network and trust created during the original roadmap process provides an ongoing mechanism for identifying when updates are needed.

A: Regular monitoring is essential. The EU uses annual progress reporting and technology-observatory assessments to track technology maturity, value chains, manufacturing capacity, and market development, supplemented by international information-sharing.

Q: What role should international coordination play in national or regional CDR roadmaps?

A: International coordination can help countries exploit complementary resources and capabilities rather than attempting to deploy every CDR pathway domestically. Cross-border opportunities may include CO_2 transport and storage, technology exports, MRV expertise, carbon credits, and joint ventures.

A: Effective roadmaps should balance domestic priorities with opportunities for international collaboration, creating clear points where countries can work together on

shared CDR challenges and opportunities.

A: International platforms such as Mission Innovation can accelerate learning by allowing governments, industry, and researchers to share experiences and best practices, while successful implementation ultimately requires joint ownership and clarity on investment responsibilities.

Panel Discussion: Moving CDR Forward Globally

Each panelist first shared their views on the future outlook for CDR, followed by a discussion among the panelists.

Andrew Lenton (Moderator), MI CDR Co-lead, Director, CarbonLock, CSIRO

Erik Rylander, Commercial Director CDR, Stockholm Exergi, Sweden

Moving CDR forward requires simultaneous progress on supply, demand, and the policy rulebook. On the supply side, early engineered-removal projects will continue to require a combination of public and private finance. European projects reaching final investment decision have typically combined private anchor buyers with state support, demonstrating the importance of “stacking” funding rather than treating public and private procurement separately. Public support schemes also need to be accessible and predictable, since developers otherwise face substantial upfront expenditures before knowing whether government support will be available.

On the demand side, voluntary markets remain important in the near term, supported by standards that help corporate buyers determine how CDR fits into credible climate strategies. However, voluntary demand alone will not deliver the required scale; compliance markets and dedicated CDR targets will ultimately be necessary. Regulatory frameworks should also become more harmonized internationally, while maintaining scientific integrity—particularly around the durability and “like-for-like” principle of matching fossil emissions with sufficiently permanent removals.

Morgan Edwards,
Executive Team, State of Carbon Dioxide Removal

As the CDR sector develops, better and more frequent data collection and knowledge sharing will become increasingly important. State of CDR reports have been produced approximately every two years, but the accelerating pace of activity may require more frequent updates. Greater availability of open data would allow stakeholders to learn from early projects, although this needs to be balanced against companies' proprietary information. Significant regional data gaps also remain, making broader geographical participation in CDR assessment and knowledge-sharing activities important.

Future assessment should go beyond tracking deployment to examine the effectiveness of policies, differences among CDR methods, regional conditions, public opinion, and social license. The sector must also address the near-term financing gap faced by startups that need to survive until larger policies and market mechanisms become operational. Finally, governance deserves greater attention: scaling CDR requires not only technologies and policies but also effective structures through which public and private actors can coordinate around shared objectives.

Juho Lipponen,
Coordinator and Acting Director, MI CDR Mission

Governments have a critical near-term role in establishing the strategic direction for CDR—clarifying what role removals should play nationally and providing a foundation from which policies on innovation, deployment, and standards can follow. Mission Innovation CDR provides a government-to-government platform through which countries can exchange experience and learn from one another, rather than acting as a regulatory body.

While MI CDR has traditionally focused strongly on technology innovation through technical tracks, its role is expanding toward deployment and enabling policy frameworks. Australia and Canada, for example, have agreed to initiate work on enabling policy frameworks. MI CDR can therefore act as a catalyst for countries to learn from each other's approaches and accelerate both CDR innovation and deployment.

Chris Neidl,
Carbon Dioxide Removal Lead, Climate High-Level Champions, UN

CDR is increasingly being integrated into broader technological, policy, economic, and social systems, rather than remaining an isolated field. This creates opportunities for CDR practitioners to engage with communities and sectors outside their traditional boundaries. Intermediaries and individuals capable of connecting different domains can therefore play an important role in expanding the CDR ecosystem.

Building these connections is not simply a formal institutional exercise. Repeated interactions, informal conversations, and relationships can generate new collaborations and reveal unexpected links between CDR and other sectors. International gatherings such as COP are valuable not only for formal negotiations but also because they concentrate diverse actors in one place, creating opportunities to build the social networks and cross-sector connections needed for CDR to become increasingly embedded in the wider economy and society.

Yukimi Shimura,
Managing Director in charge of Corporate Engagement on GX and Sustainability, MUFG Bank, Ltd., Japan

Scaling CDR ultimately requires viable business models. Projects need both lower costs and predictable revenues: technology development and public CAPEX support can help reduce costs, while stronger demand mechanisms are needed to provide reliable revenue. Government procurement could provide an important initial source of demand and support first movers, but broader mechanisms will subsequently be required to bring second movers into the market and eventually enable more market-driven deployment.

National policy signals are especially important for corporate action in Japan and Asia. Incorporating CDR into national targets or NDCs could encourage companies to establish their own CDR strategies. Integrating CDR into compliance markets remains challenging because current carbon prices may be substantially below CDR costs, meaning that mechanisms such as public OPEX support or contracts for difference may be necessary during the transition. Different countries will nevertheless require different pathways depending on resources, policy readiness, and institutional capacity, making national roadmaps and capacity building important components of market

development.

Discussion :

Q: What is needed to make CDR projects financeable and create sufficient demand?

A: From a financier's perspective, credible demand and long-term offtake are essential because lenders need confidence in predictable project revenues. Scaling CDR therefore requires demand mechanisms that extend beyond the relatively small number of projects currently able to secure strong long-term offtake agreements.

A: Waiting for CDR costs to fall before creating demand creates a chicken-and-egg problem: costs decline through learning from deployed projects, but projects cannot proceed without early buyers. Public and private funding should therefore mobilize early projects, with contributions pooled from a broader set of buyers rather than relying only on large technology companies.

A: Demand itself can also become more modular. Instead of relying exclusively on large corporate offtakes, removals could be embedded into products, buildings, portfolios, or other purchasing structures, allowing smaller contributions to aggregate into meaningful demand.

Q: What indicators would demonstrate that global CDR is moving in the right direction?

A: Novel CDR is already growing, but from a very small base. The key signal would be sustained year-on-year growth that is resilient to temporary disruptions at individual projects. Another indicator would be increasing normalization of CDR in society, reflected in broader public awareness, media coverage, and integration into ordinary business and societal discussions.

Q: What should effective international collaboration on CDR look like, and what role can COP play?

A: International cooperation involves both formal institutions and informal networks.

Informal conversations build trust and generate ideas that can later develop into formal initiatives. COP is particularly valuable because it brings governments, businesses, civil society, and other actors together, enabling both formal policy progress and the repeated interpersonal engagement through which new collaborations emerge.

Q: How should the role of Mission Innovation CDR evolve?

A: MI CDR can use its direct links with governments and ministerial processes to bring CDR messages into high-level policy discussions while maintaining a continuous community of practitioners between major events. Its role should expand beyond technology innovation toward large-scale deployment strategies, enabling policies, and practical near-term action.

A: Its informal network is also valuable because practitioners can exchange granular experiences that may not emerge through formal policy discussions. MI CDR can connect bottom-up industry knowledge with top-down government policymaking and facilitate international learning between countries pursuing different approaches.

Q: How can Global South participate more fully in CDR innovation and deployment?

A: International platforms should engage more actively with countries such as Kenya, Brazil, and others, while enabling countries with more established CDR policies to share experience and capacity.

A: The Global South should not be viewed merely as a recipient of technologies developed elsewhere. Countries such as Kenya, Brazil, and India already possess substantial technological, research, resource, and deployment capabilities, meaning that innovation and knowledge could also flow from the Global South to other regions.

A: Greater inclusion of researchers and practitioners from these regions in international assessments, road mapping, and research collaborations would improve understanding of regional CDR opportunities while ensuring that local expertise shapes deployment strategies.

Q: Could product-level approaches help expand corporate demand for CDR?

A: Product-level approaches could allow companies to address emissions associated with products rather than requiring them to neutralize their entire corporate footprint at once. Such approaches should maintain full transparency, clearly distinguish emissions reductions from removals, and avoid claims that obscure the actual emissions associated with the product.

A: Product-level purchasing could also make CDR more accessible to consumers and companies by linking measurable atmospheric carbon removal to specific purchasing decisions. Starting with relatively simple and transparent applications may be more practical than attempting to resolve every accounting issue at once.

Q: How should engineered and nature-based removals be brought together?

A: Rather than treating engineered and nature-based CDR as competing approaches, portfolio-based purchasing could combine their respective advantages. Durable removals could reduce some of the permanence risks associated with nature-based removals, while nature-based approaches could lower portfolio costs and expand demand. Concepts such as contracted durability and carbon-at-risk therefore deserve further exploration, although mechanisms need to provide sufficiently predictable demand for durable-removal projects.

Q: How can the scale and urgency of CDR be communicated to the wider public?

A: CDR needs to start scaling now because technological development and deployment take decades—even technologies perceived as having scaled rapidly, such as solar power, required long periods of development. Communicating this time lag can help explain why investment is needed well before very large-scale removals are required.

A: Public education needs to begin with broader climate-change understanding rather than CDR alone. At the same time, companies and other actors should build real projects and small communities of interested stakeholders rather than waiting for public awareness to become universal. Education, market creation, and project development therefore need to proceed in parallel.

A: Familiar analogies can also help. One useful framing is to describe CO_2 as a waste product that society needs to manage, connecting CDR to everyday expectations around waste-management systems.

Q: What gives the panelists optimism about the future of CDR?

A: The panel highlighted several positive signals: the underlying technologies are increasingly understood; awareness is growing; the CDR community is expanding; entrepreneurial activity and startups are proliferating; and companies are beginning to look beyond their 2030 climate targets. Together, these developments suggest that CDR is becoming a more established component of longer-term climate strategies, even though substantial scaling challenges remain.

CDR Mission Key takeaways from the event

Juho Lipponen,
Coordinator and Acting Director, MI CDR Mission

Over the past two days, we have explored CDR from a broad range of perspectives, including technology, markets, materials, policy, finance, standards, roadmaps, and global collaboration. The discussion highlighted three key themes: deployment, implementation, and mobilization. First, the scale of the deployment challenge is significant, and the numbers discussed during the workshop reinforce the urgency of accelerating our efforts. Second, we need to move from discussion toward implementation across multiple areas—including innovation, policy, finance, and roadmaps—and use these discussions as a “strategic compass” for future action.

Third, we need to mobilize the wider CDR community. We should all act as “policy entrepreneurs,” bringing CDR into relevant forums, building coalitions, and creating new partnerships. MI CDR will take the insights from this workshop forward through its technical tracks and its new work on enabling policy frameworks. Our upcoming ministerial meeting in Riyadh will also provide an important opportunity to bring these messages into minister-level discussions and continue building momentum for CDR internationally.

Closing remarks

Hiroki Watanabe,
Director, International Affairs Office, Innovation and Environment Policy Bureau, Ministry of Economy, Trade and Industry, Japan

This workshop was designed not simply as a forum for sharing information, but as an opportunity to promote open dialogue across governments, researchers, industry, investors, and other stakeholders. The panel discussions and breakout sessions demonstrated the value of bringing together different perspectives, while the growing participation in the workshop reflects the continued expansion of the global CDR community.

One of the clearest messages from the workshop is that advancing CDR requires continued international cooperation. No single country or organization can address the challenge alone, and Japan places strong importance on deepening partnerships with countries, companies, and organizations around the world. I hope the discussions in Tokyo will contribute to the MI CDR Mission's goal of reaching 100 million tons of CO_2 removal by 2030, and that the relationships built here will develop into new partnerships and concrete actions in the years ahead.

Appendix 1: Program Outline

Mission Innovation
CDR Mission - Tokyo Workshop Ⅱ

CDR: Exploring Practical Pathways for Innovation and Scale-up

September 10 (Thu) – 11 (Fri) 2026
Bellesalle Roppongi Grand Conference Center, Tokyo

Program for In-person Attendees (Final Agenda)

Objective	This workshop follows from the first METI & MI CDR Tokyo event of October 2025, with the objective to further support the deployment and expansion of Carbon Dioxide Removal (CDR). The event agenda will discuss and build on recent market, policy and technology developments and analytical insights, with the aim of finding solutions to barriers to deployment. Speakers and participants will identify and discuss key enablers for scaling up CDR, while incorporating various national perspectives. The workshop aims to strengthen shared understanding of key challenges and opportunities, and create connections among speakers and participants, supporting future collaboration and progress.
Date	September 10 (Thu) – 11 (Fri) 2026
Location	Bellesalle Roppongi Grand Conference Center, Tokyo Address: 9F 3-2-1 Roppongi, Minato City, Tokyo 106-6209
Format	Hybrid (On-site: by invitation only; Capacity: on-site 60-100, online 100-200(Webex))
Host	Ministry of Economy, Trade and Industry, Japan
Main Sessions	1. CDR Landscape 2. CDR Scale-up Challenges 3. Breakouts 4. Designing Pathways Forward 5. Networking sessions
Registration (for in-person participation)	Register here: https://forms.office.com/r/SeghZmDssD?origin=lprLink&lang=en-US
Others	*The workshop recording will be available for registered participants for 10 days after the event.* *-Simultaneous English-Japanese interpretation will be provided.*

[1] September 10 (Thu)

1. CDR Landscape

9:30 - 9:45 Welcome Address

- *Deputy Director-General, Ministry of Economy, Trade and Industry, Japan - name tbc*
- ***Joanna Drake**, Deputy Director-General of DG Research & Innovation, European Commission*
- ***Moneer T Alsubaie**, MI CDR Co-lead, Sustainability and Climate Change Engineer, Ministry of Energy, Kingdom of Saudi Arabia*

9:45 - 10:15 Keynote: CDR Today

State of CDR: an update on global status and progress, including Q&A

- ***Morgan Edwards**, Executive Team, State of Carbon Dioxide Removal*

10:15 - 10:45 Keynote: Novel CDR and developments towards COP31

An update on novel CDR developments at COP31, covering progress on CDR2030, including Q&A.

- ***Chris Neidl,*** *Carbon Dioxide Removal Lead, UN Climate High-Level Champions*

10:45 - 11:15 Morning Coffee

11:15 - 11:45 Keynote: Novel CDR Markets

CDR market update, including Q&A

- ***Tank Chen,*** *Head of Community & Content, CDR.fyi*

2. CDR Scale-up Challenges

11:45 - 12:30 Market Perspectives

This session discusses the current status and future opportunities for markets, from the viewpoint of buyers, sellers and market places, to facilitate and drive CDR scale up. Each panelist has a 5 - 7 minute introduction, followed by a panel discussion.

Moderator: ***Tank Chen,*** *Head of Community & Content, CDR.fyi*

- ***Erik Rylander,*** *Commercial Director CDR, Stockholm Exergi, Sweden*
- ***Omar Alajaji,*** *Advisory Services Sector Manager, Regional Voluntary Carbon Market Company (RVCMC), Kingdom of Saudi Arabia*
- ***Tadashi Sawamura,*** *General Manager, Carbon Management Dept. Europe & Next-Generation Energy Div. Energy & Power Solution Group, Mitsubishi Corporation, Japan*

12:30 - 13:30 Lunch Break

13:30 - 14:30 Non-technical Enablers

This session discusses various non-technical levers, such as finance, risk-sharing, demand-creation etc. that can drive scale. Each panelist has a 5 - 7 minute introduction, followed by a panel discussion.

Moderator: ***Christopher Toews,*** *Director, Energy Innovation Policy, Office of Energy Research and Development, Natural Resources Canada*

- ***Yukimi Shimura,*** *Managing Director in charge of Corporate Engagement on GX and Sustainability, Sustainable Business Division MUFG Bank, Ltd., Japan*
- ***Marianne Bruvoll,*** *Senior Sustainability Business Analyst, Nordea, Norway*
- ***Kash Burchett,*** *Global Head of Carbon Removal Technologies, Climate Transition Team, Group Sustainability, HSBC HOLDINGS PLC, Hong Kong*
- ***Joel Gould,*** *Markets & Policy Lead, BeZero Carbon, UK*

14:30 - 15:00 Keynote: Geographical Advantages and Constraints for Scaling CDR

This session explores how geographical factors influence the feasibility and scale-up of CDR across regions.

- ***Shinichirou Morimoto,*** *Deputy Director / CCUS Assessment Research Team Leader, Integrated Research Center for CCUS Implementation, Carbon Management Research Team Leader, Global Zero Emission Research Center, AIST, Japan*

15:00 - 15:30 Afternoon Coffee

15:30 - 16:30 Technology Enablers

This session explores how technology approaches, system design, and innovation pathways enable CDR scale-up, with a focus on practical challenges identified through real-world deployment and approaches to overcome these. Each speaker will have a 7 - 10 minute introduction each, followed by a panel discussion or Q&A.
Moderator: ***Atul Sharma****, Principal Researcher, Global Zero Emission Research Center (GZR), AIST*

- ***Akihito Yamashita****, Senior Staff Officer, CN Business Strategy Office, Energy Solution & Marine Engineering Company, Kawasaki Heavy Industries, Ltd., Japan*
- ***Hanna Ojanen****, Head of Carbon Markets and Policy, Carbo Culture, Finland*
- ***Edda Sif Pind Aradóttir****, CEO, Carbfix, Iceland*
- ***Kel Coulson****, Director of International Policy, OxyCarbon Engineering, Canada*

3. Breakouts

16:30 - 17:30 Breakout Discussions: Strategic Dimensions of CDR Scale-up

The breakout discussions will explore unresolved questions and strategic choices from different complementary perspectives.
Overall Theme: "Key enablers for rapid CDR scale-up"

Breakout A: Demand Signals, Market Confidence, and Implications for CDR Developers - Assess how changes in demand patterns, buyer behavior, and market confidence influence investment conditions and future CDR market and project development.

Breakout B: Demand Signals, Market Confidence, and Implications for CDR Buyers – Discuss the importance of instruments such as buyers' clubs and other initiatives in creating and sustaining CDR demand.

Breakout C: Technology Readiness, Demonstration, and Implications for CDR Scale-up - Assess how **technology readiness** and large-scale demonstration affect the scalability and risk profile of CDR projects.

17:30 - 17:35 Wrap up of Day 1

- ***Andrew Lenton****, MI CDR Co-lead, Director, CarbonLock, CSIRO, Australia*

[2] September 11 (Fri)

9:30 - 9:40 Welcome to Day 2

Brief recap of Day 1 messages and outlook to Day 2.

- ***Juho Lipponen****, Coordinator and Acting Director, MI CDR Mission*

4. Designing Pathways Forward

9:40 - 10:00 Keynote: Accelerating Materials Innovation for Clean Energy

This session highlights Mission Innovation's "Materials for Energy" (M4E) initiative and its efforts to accelerate advanced materials development for clean energy, focusing on key approaches such as international collaboration and AI-driven discovery, including Q&A.

- ***Christopher Toews****, Director, Energy Innovation Policy, Office of Energy Research and Development, Natural Resources Canada, Canada*

10:00 - 10:20 Keynote: Materials Innovation to Scalable Carbon Removal

This session highlights how advanced materials enable new approaches to carbon removal, focusing on practical challenges and pathways to scale from pilot to deployment, including Q&A.

- ***Dai Kataoka,*** *Managing Director & COO, Atomis Inc., Japan*

10:20 - 10:40 Keynote: The 2027 IPCC CCS & CDR Methodology Report - state of play and implications for CDR deployment

This session highlights IPCC's forthcoming 2027 IPCC CDR/CCUS methodology report and provides an overview of the latest perspectives on CDR technologies, MRV, including Q&A.

- ***Takao Nakagaki,*** *Professor, Faculty of Science and Engineering, Waseda University / 2027 IPCC CDR/CCUS methodology report coordinating lead author, Japan*

10:40 - 11:00 Morning Coffee

11:00 - 11:45 Building Trust at Scale: Standards, Market Infrastructure, and Risk Management

This panel discussion will focus on how to build trust, credibility, and manageability into CDR markets at scale, through standards, enabling infrastructure, and approaches to risk management and social acceptance.
A 7 - 10 minute introduction each, followed by a panel discussion.
Moderator: ***Morgan Edwards,*** *Executive Team, State of Carbon Dioxide Removal*

- ***Antti Vihavainen,*** *Vice Chairman, Puro.earth, Finland*
- ***Delia Meth-Cohn,*** *Co-Founder, Rethinking Removals, UK*
- ***Joel Gould,*** *Markets & Policy Lead, BeZero Carbon, UK*

11:45 – 12:45 National Policies and Activities

This session highlights recent national policy developments, strategies, and initiatives for CDR, as well as challenges for scaling CDR globally. A 7 - 10 minute introduction each, followed by a panel discussion.
Moderator: ***Kash Burchett,*** *Global Head of Carbon Removal Technologies, the Climate Transition Team, in Group Sustainability, HSBC*

- ***Rufaydah H Alyamani,*** *International Initiatives Team Lead, Ministry of Energy, Kingdom of Saudi Arabia*
- ***Keiji Hisata,*** *Senior Negotiator for Climate Change Global Environmental Affairs Office GX Policy Group, Ministry of Economy, Trade and Industry, Japan*
- ***Christopher Toews,*** *Director, Energy Innovation Policy, Office of Energy Research and Development, Natural Resources Canada*
- ***Belladonna Maulanda,*** *Executive Director, Indonesia CCS Center*

12:45 – 13:45 Lunch Break

13:45 - 14:00 MI CDR "SMART CDR Competition": The Journey of a Japanese Start-up

The 2025 SMART-CDR Competition winner from Japan will share their progress and the impact of the competition on their development.

- ***Ryoya Sato,*** *Second-year master's student, Graduate School of Engineering, Hokkaido University, CDR^2 (CDR squared), Japan*

14:00 - 15:00 From Insights to Action: Building CDR Roadmaps

This session will discuss how roadmaps can be used as tools to accelerate CDR development and deployment. Building on earlier sessions and showcasing recent national and regional roadmap developments, the speakers will discuss key elements of roadmaps, focusing on prioritization, sequencing, and stakeholder roles. The session will also identify implications for international coordination, including global governance considerations and potential instruments. A 7 - 10 minute introduction each, followed by a panel discussion.

Moderator: ***Delia Meth-Cohn****, Co-Founder, Rethinking Removals*

- ***Alexander Makela,*** *Chief Policy Officer, Carbon Gap*
- ***Andrew Lenton,*** *MI CDR Co-lead, Director CarbonLock, CSIRO, Australia*
- ***Jeroen Schuppers,*** *Senior Expert, European Commission*
- ***Koji Kojima,*** *Japan CDR Coalition, Advisory Associate, Future Co-Creation Group, Customer Relations Division Mitsubishi Research Institute, Inc., Japan*

15:00 - 15:30 Afternoon Coffee

15:30 - 16:50 Panel Discussion: Moving CDR Forward Globally

The final session will wrap up the event, by looking into the key next steps, including the global challenges, opportunities to advance CDR across different technologies, coordination and knowledge-sharing across markets, policies, and stakeholders, as well as the key requirements for strengthening global collaborations and coalitions.

Moderator: ***Andrew Lenton,*** *MI CDR Co-lead, Director, CarbonLock, CSIRO*

- ***Chris Neidl,*** *Carbon Dioxide Removal Lead, Climate High-Level Champions, UN*
- ***Morgan Edwards,*** *Executive Team, State of Carbon Dioxide Removal*
- ***Juho Lipponen,*** *Coordinator and Acting Director, MI CDR Mission*
- ***Erik Rylander,*** *Commercial Director CDR, Stockholm Exergi, Sweden*
- ***Yukimi Shimura,*** *Managing Director in charge of Corporate Engagement on GX and Sustainability, MUFG Bank, Ltd., Japan*

16:50 - 16:55 CDR Mission Key takeaways from the event

- ***Juho Lipponen,*** *Coordinator and Acting Director, MI CDR Mission*

16:55 - 17:00 Closing remarks

- ***Hiroki Watanabe,*** *Director, International Affairs Office, Innovation and Environment Policy Bureau, Ministry of Economy, Trade and Industry, Japan*

5. Networking sessions

17:30 - 20:00 Networking

This session enables informal exchange and exploration of collaboration opportunities kindly hosted by the Delegation of the European Union to Japan.

- ***Venue: ANA InterContinental Hotel, Tokyo***
  Address: 1-12-33, Akasaka, Minato City, 107-0052



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