CARBON DIOXIDE REMOVAL MISSION

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Technical Track on Biomass Carbon Removal and Storage (BiCRS)

Scope of Work

Version 1.0

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1. Introduction

The Carbon Dioxide Removal (CDR) Mission, under Mission Innovation (MI), aims to enable CDR technologies to achieve a net reduction of 100 million tonnes of CO_2 per year by 2030. The CDR Mission is co-led by the US, Canada, and the Kingdom of Saudi Arabia. Members are Australia, the European Commission, India, Japan, Norway, and the United Kingdom.

The CDR Mission will work on three technical tracks:

- Direct Air Capture (DAC)
- Enhanced Mineralization
- Biomass with Carbon Removal and Storage (BiCRS)

and a cross-cutting track on Life Cycle Analysis (LCA) and Techno-Economic Analysis (TEA), which aims to develop consistent cradle-to-grave system boundaries, harmonize variables (e.g., land, process, temporal), enable access to high-quality data, and develop methods to measure, report, and verify carbon (MRV) removals.

1.1. The BiCRS Track – what is included

Japan and Norway are co-leads for the BiCRS technical track. By October 2022, participants are Australia, Canada, EU, India, UK and USA.

For the purpose of structuring and limiting the work of the BiCRS track, the following precisions will be introduced:

- Biomass is defined as terrestrial and marine plants, woods, biogenic residues, including manure and the biological part of non-hazardous municipal waste.
- To be considered net negative the BiCRS pathway must document that[1]
    - The gross removal from the atmosphere exceeds all emissions of greenhouse gases from the process in the life cycle system.
    - The removed CO_2 remains securely stored or locked away from the atmosphere in products in a manner intended to be permanent.
    - Pay due considerations to the United Nations Sustainable Development Goals (UN SDGs) in the relevant contexts (nationally, regionally).

[1] The first two points based on Tanzer and Ramirez (2019) When are negative emissions negative emissions? Energy & Environmental Science, 12(4), 1210-1218. https://doi.org/10.1039/c8ee03338b. The third point is added here, modified from the Innovation Roadmap.

In line with the MI CDR Mission's Innovation Roadmap and Action Plan[2], the three top priorities of the BiCRS technical track are:

1. Biomass feedstocks.
2. System (logistics) – including biomass resource evaluation and value-chains.
3. Utilization – including the development of higher value, long-lived products, as well as technologies adapted to "cascading principles" for use of biomass

These are included in the scope, albeit with different words and under different headlines.

The focus of the work will be challenges of engineered and hybrid (combination of engineered and natural) CO_2 removal approaches. This is in line with MI CDR Innovation Roadmap. However, non-technical issues such as public acceptance, financial and policy incentives, MRV guidelines and certification of removals, and governance challenges are important for the technical tracks to understand challenges. These issues will be included to the extent necessary and in cooperation with the cross-cutting LCA/TEA technical track.

This work scope is focused on engineered or hybrid CDR approaches, in which biomass is converted to products like power, fuels, biochar for soil carbon sequestration or industrial use, and building materials, and the biogenic CO_2 is durably stored. Storage may be in geologic formations or in long-lived products. **Ocean-based or entirely nature-based CDR concepts such as afforestation, improved forest management, wetland restoration, or other approaches where biomass is grown solely for the purpose of CO_2 storage, may be included if they are within members' interest and portfolios.**

1.2. Purpose of this document

This document is the first version of a work scope for the MI CDR BiCRS technical track. The scope is based on the MI CDR Innovation Roadmap and discussion amongst the BiCRS track countries in a virtual workshop June 21, 2022.

The purpose of this document is to outline the proposed work of the BiCRS technical track, with the objective to

- Obtain an agreed scope of work by getting feedback from all participants.
- **Lay the basis for a shared workload and responsibilities by inviting participants to select and take responsibility for work tasks that fit their competence and capacity, including suggesting new tasks.**
- Make it easier to attract potential new members to the track and inform where their competence will be useful.

NOTE*:* This is a draft work plan and a living document, with potential activities and intended to initiate discussion and, hopefully, encourage volunteers among members of the track to raise their hand and perform these tasks or suggest and perform other

[2] The Roadmap and Action Plan can be found at http://mission-innovation.net/wp-content/uploads/2022/09/Attachment-1-CDR-Mission-Roadmap-Sept-22.pdf/

supporting tasks. For example, the co-leads are open to discuss how approaches leaning more towards natural processes and the non-technical issues can be included.

The co-leads encourage input, changes, and comments of any kind. In particular they encourage track members to volunteer for specific work tasks.

2. BiCRS Technical Track – commitments, roles, and responsibilities

Each member of the BiCRS track commits to be an active part of a knowledge sharing forum across all countries to identify key challenges and to supply documents and other information needed to perform the agreed work. Countries could also commit to supporting the implementation and demonstration of promising technologies.

If the members of the track agree to common calls, the main rule is that each members fund their own participating research organizations. If funds shall cross borders, it shall be after unanimous agreement and according to agreed rules for what to fund, for contributions and for distribution of the funds.

The co-leads (Norway and Japan) will:

- Coordinate the work by:
    - Suggesting work programme and modify as needed after input from members.
    - Initiate workshops on relevant topics within the track.
    - Being a consistent driver to keep timelines, for production of reports and organizing workshops.
- Initiate and contribute to common calls and commit to funding as agreed.
- Compile/synthesize/summarizing input from members, workshops, and stakeholders to final reports and/or other products

All Member countries of the track will:

- Be active parts of a knowledge sharing forum.
- Perform tasks and studies, and supply information/data as agreed.
- Provide input and comments as requested to plans, reports etc.
- Volunteer to perform tasks and studies.
- Supply information/data as agreed.
- Take active part in the organization and executing of workshops.
- Suggest and contribute to common calls and commit to funding as agreed.
- Involve research community, private industry, academia, and other relevant stakeholders in agreed countries to participate in Mission activities within BiCRS.

3. Timeline

Execution of the scope depends heavily on available resources amongst the track member countries. Japan and Norway propose the following tentative timeline:

- *Work scope with volunteers for tasks as agreed: End October 2022.*
- *Phase 1 starts: Mid-November, 2022.*
- *Phase 1 completed: Tentatively December 1, 2023 but some sub-tasks will have to work in progress.*
- *Phase 2 starts: May 1, 2023*

4.Work plan

The work plan for BiCRS will be carried out in phases and Work packages (WPs).

Phase 1, consisting of WP1 and WP2, will map biomass resources, potential industrial users and conducted LCAs. This phase will contribute to the CDR Missions' Short-term Outcome[3] #1: "Enhanced understanding of local and global CDR potential".

The WPs give important background information for further work. They will mainly use existing information and expected to be moderately resource demanding. The work will be focussed on, but not necessarily, limited to approaches that capture and permanently remove from the atmosphere CO_2 generated from combustion or conversion[4] of biomass to useful products (e.g. to heat, electricity hydrogen, liquid fuels, other potential industrial feedstocks, biochar, or building materials in way that results in net negative emissions. These processes are included in the term BioCCS, as described in the Innovation Roadmap.

It is proposed that Phase 1 of the work plan will start for 'lighthouse' countries/regions, specifically the Nordic countries (lead by Norway), which form an innovative region with different types of biomass, bio-related industries and CO_2 storage options available. Other regions/countries may be added if there are volunteers. Further work will be based on the learnings from this phase.

Phase 2, consisting of WPs 3-5, will contribute to the CDR Mission's Short-term Outcome #2: "Advancement of Research and Development (R&D) for CDR" and the Short-Term Outcome #3: "Global demonstrations and Pilot-Scale Tests".

WPs 3-5 are formulated to meet most of the challenges in the Innovation Roadmap. They will require new and partly ground-breaking work, thus significant resources that it may take time to muster.

[3] For Short-term Outcomes, see Carbon Dioxide Removal Mission – Action Plan 2022-26 (http://mission-innovation.net/wp-content/uploads/2022/09/Attachment-2-Public-Facing-CDR-Mission-Action-Plan-Sept-2022.pdf)

[4] Here conversion processes include including pyrolysis, gasification and other thermochemical process, as well as termochemical, mechanical/chemical, thermobiochemical and biochemical process as described in the Innovation Roadmap

4.1. Phase 1

WP1 - Mapping and characterizing biomass feedstock resource

Biomass feedstock exists and is used in many forms, amounts and availability[5]. There may be competition for the resources. Therefore, data that allow assessment of supply chain logistics will be necessary. This will include locations of the various biomass resources relative to potential user industries, transport, and suitable geologic storage.

The overall purpose of WP1 is:

- Map biomass feedstock in relation to use/applications, transport possibilities and storage sites at national/regional levels.

The work may be divided into two phases

- Phase 1a: map the biomass resource supply.
- Phase 1b: map the current and potential industrial users.

Phase 1b can then give a sense of whether biomass consumption in a particular region is over- or under-utilized.

Mapping tasks include but are not limited to (tasks can also be removed if members do not have capacity and /or competence):

- **Phase 1a**
    - Identifying, compiling, and synthetizing existing information on location and availability of various biomass feedstocks, including agricultural, forest and aquatic resources.
    - Indicating the suitability for potential applications. (Collection of new information will only be initiated if agreed by members and resources allow).
    - Performing an initial identification of potential national or regional trade-offs, including sustainability issues. However, this will be an evolving task.

- **Phase 1b**
    - Identifying and contacting industries/companies with existing or planned biomass conversion facilities to obtain information on use, technology and experience.
    - Identifying and contacting industries/companies that plan to use biomass in their process, e.g. for heat production or biochar as reducing agent in the metallurgic industry
    - Identifying and contacting other industries and other potential stakeholders and users.
    - Using the mapping results to initiate networks of industry groups.

[5] Examples of existing uses, see the MI CDR Innovation Roadmap (http://mission-innovation.net/wp-content/uploads/2022/09/Attachment-1-CDR-Mission-Roadmap-Sept-22.pdf).

- Using existing information to locate storage sites. Atlases of CO_2 storage sites with the necessary information are available from most of the MI CDR members and many other countries/regions. This task will be common to the DAC technical track.
- Using existing information to locate infrastructures for transport of CO_2, with indications of capacities and availability. Existing CO_2 transport pipelines will form the basis for the work.
- Identifying and synthesize information and challenges related to transport of biomass to conversion facilities and markets.

In addition, WP1 should include:

- Identification of knowledge gaps with regards to sustainability, how biomass utilization can be optimized, and the ability of biomass feedstocks to contribute to CDR.
- Exemplifying and summarizing the cascading principle on use of wood and biomass-based products, including use/recirculation of residues from combustion or conversion of biomass.

WP1 **may** also include, if agreed by members and resources allow:

- Mapping national and international regulations for uptake and development of BiCRS (will be useful also for other technical tracks, may be this could be common to all CDR technical tracks)
  - Enhancing understanding of regional and international regulations would also help the private sector.
  - Within member countries, understand the regional and international regulations impacting BiCRS technologies to encourage and scope the update and support

Outcomes of WP1:

- Collection of maps or reports on common website. **NOTE: Full digitalization of results and harmonization, will, if agreed to be necessary, be part of a later phase of the mapping process.**
- Guidelines or recommendations on further work on sustainability and optimization (for WP4 – R&D).
- Guidelines or recommendations for further work on transport of biomass (for WP4 – R&D).
- Networks for groups of industries, in particular Waste-to-energy facilities (some already exist).

Timeline:
Start: Phase 1a fall 2022, Phase 1b June 2023.
End: Tentatively December 2023 but some sub-tasks will have to work in progress.

WP2 - Harmonize LCA/TEA methodology for BiCRS

LCA for engineered CDR approaches is challenging due to factors that include insufficient or diverging data, use of different system boundaries, and confusion between removed and replaced CO_2 (MI CDR Innovation Roadmap). Some considerations are:

- There is a need for:
  - Examples.
  - A common approach/method.
  - Case studies that allow cross-country comparisons.
- Accounting for dynamic nature of CO_2 absorption and release for biomass.
- The permanency of storage (beyond 100 years).

The purpose of WP2 is:

- Improve understanding of differences and shortcomings in LCA for BiCRS.

MI CDR has a separate and dedicated technical track for LCA and TEA. The BiCRS track will have to work with the cross-cutting technical track (LCA/TEA). However, the BiCRS technical track will undertake some dedicated tasks:

- Identifying LCAs performed within the relevant BiCRS topics in the lighthouse region(s).
- Evaluating differences in results and methods.
- Performing LCA for at least two cases, each with at least two different approaches.
- The LCAs must document how they address factors like climate impacts of direct and indirect land use, land use change and forestry, competition with other uses of land, water consumption, and impacts on biodiversity, the carbon, nutrient, and hydrological cycles, as well as trade-offs with the UN Sustainability Goals. The LCAs must also address non-climate impacts, such as ecotoxicity and eutrophication.
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- Evaluating the results in form of differences in results and methods and convey to the LCA/TEA technical track for improvement (in cooperation).

Outcome of WP2:

- Recommendations to the LCA/TEA Technical Track on how LCA for BiCRS can be improved.

Timeline:
Start late 2022/early 2023.
End: Tentatively December 2023 but this will be an evolving process.

In the longer run, WP2 may be expanded to include broader system analysis and a sustainable transition pathway.

4.2. Phase 2

WP3 – Utilization with long-term carbon removal (preliminary scope)

Generating bio-based products creates a revenue stream for facilities but lack the process efficiency to generate products that are low enough in cost compared to mature fossil fuel-based products with established value chains. Moreover, some bio-products will have a challenge achieving CDR status (net negative CO_{2e} on a life cycle basis).

The purpose of WP3 is:

- Developing higher value, long-lived products), with proven net negative in a manner intended to be permanent and understanding their long-term environmental impact.

WP3 tasks could include (details in the MI CDR Innovation Roadmap):

- Developing technologies adapted to "cascading principles" for the use of biomass.
- Optimizing for fuel switching (from fossils to biomass; where, when and how). This should be in cooperation with the MI Missions for Industries band Biorefineries.
- Quantification of biochar carbon sequestration permanence and understanding how biochar soil amendments affect agricultural productivity, water use, and albedo.
- Development of advanced construction techniques and new application areas for long-lived engineered wood products.
- Development of long-lived bio-based chemical products and bio-fiber concrete.
- Use of biomass in the process industry.
- Performing LCAs for the products.

Outcomes of WP3:

- Technologies for the production of high value and long-lived products with net negative emissions in a manner intended to be permanent.
- LCAs for products.

Timeline: To be decided, depending on resources.

WP4 – Research and Development (preliminary scope)

Many technology elements required for BiCRS are already mature and commercially available at scale today in global supply chains. High cost, non-technical issue, and potential conflicts with the UNSDGs (e.g. food security and biodiversity remain challenges. Improvements are possible through R&D investments in existing and emerging technologies and by learning by doing.

The purpose of WP4 is:

- Driving down costs of conversion of biomass feedstocks and the capture of biogenic CO_2.
- Improving understanding of the benefits and trade-offs of BiCRS approaches.

WP4 tasks could include (details in the MI CDR Innovation Roadmap):

- RD&D on energy- and cost-efficient conversion and capture technologies.

- RD&D on use of biomass in energy and fossil fuel intensive industries, e.g. as reducing agent in metallurgic industries.
- RD&D on energy- and cost-efficient integration of biomass conversion with CO2 capture.
- RD&D on sustainability of biomass feedstocks and biomass feedstock that is optimized for life-cycle carbon removal, including genetically modified biomass to increase uptake of carbon without increasing environmental impacts in a life cycle's perspective.
- RD&D on cultivation of macroalgae in marine waters at large scales while minimizing ecological risks.
- RD&D on optimal biomass densification, pre-treatment, and formation techniques.
- RD&D on challenges related to transport of biomass to conversion facilities and markets.

Outcome of WP4:

- Improved technical solutions for biomass conversion, combustion and use as feedstock in industry with respect to energy, water, land use, and cost as they relate to carbon capture technologies for CDR.
- Guidelines for the sustainable use of biomass feedstocks for the various carbon capture technologies and approaches, e.g., pre-combustion vs. post-combustion and so forth.
- Checklist for developing innovative biomass to enhance carbon uptake and capture.

Alternatives for funding and execution of WP4 include:

- Funded and carried out purely at the national/regional level.
- Joint calls where participating organizations work on the same topic/problem but where the main rule is that each member country fund their own participating research organizations.

Timeline: To be decided, depending on resources.

WP5 – Pilots and demonstration facilities (preliminary scope)

It is imperative to gain experience from operating facilities for further implementation and upscaling of BiCRS including data for LCA/TEA.

The purpose of WP5:

- Pave the ground for build-out of pilot and demonstration bioCCS facilities.

The task of WP5 could include:

- Facilitate knowledge transfer between stakeholders with operating facilities and those that are in the planning phase, including engineering, permitting, and operating phases and other relevant information. The knowledge transfer will include:
    - Relevant documentation, with due consideration to IPR and proprietary information.

    - Workshops, with participation by and dialogue between experienced and future owners/operating organizations, engineering companies, permitting entities and funding organizations.
- Facilitate funding opportunities, private as well as public at the national/regional levels.

Outcome of WP5:

- 1000 tonnes CO_2 year pilot/demonstration facilitates in construction by 2025.

Timeline: To be decided, depending on resources.