# CCUS R&I Priorities

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Areas of importance for R&I activities – input to DG RTD, European Commission (EC), by the Zero Emissions Platform (ZEP) and the European Energy Research Alliance (EERA) and with input from the CCUS SET-plan IMPACTS9 consortium. A draft of this document, highlighting the most important areas, was shared with Vassilios Kougionas (who is leading the EC CCUS co-creation group) and discussed in the SET-plan Strategic Coordination Group on Tuesday 11 February. We also refer to the Mission Innovation CCUS Challenge Priority Research Directions Report[1] and Report of the Mission Innovation Carbon Capture, Utilization and Storage Experts' Workshop of June 2019[2].

## *Basis*

The basis for the CCUS R&I priorities is the political EU climate ambition, highlighted in the European Green Deal and in the European Climate Law. CCS, CCU and low-carbon hydrogen will be crucial in order to reach these targets. It will be crucial:

- to implement CCS and CCU technologies at scale now.
- to accelerate the deployment of large-scale CO2 transport and storage networks, which enable clean, competitive energy (power, heating and transport) and industrial sectors, including early large-scale clean hydrogen and climate positive solutions (negative emissions).

For this to be possible, conditions necessary to reach net-zero GHG emissions in Europe by 2050 with a focus on energy and industrial sectors must be determined and created in the political economy.

The European Union is responsible to create a favourable environment for clean investments.

## *Socio economic context*

With the communication on the European Green Deal and the consequent proposed regulations, establishing a Just Transition Mechanism and a framework for a European

[1] http://mission-innovation.net/wp-content/uploads/2018/09/Accelerating-Breakthrough-Innovation-in-Carbon-Capture-Utilization-and-Storage-_0.pdf

[2] http://mission-innovation.net/wp-content/uploads/2019/11/CCUS-Mission-Innovation-Challenge-Workshop-Report-Trondheim-2019.pdf

Climate Law, the EC set out an ambitious trajectory to net-zero greenhouse gas emissions by 2050. The European Climate Law also highlights that all upcoming pieces of legislations will need to be consistent with the target of net-zero. Additionally, the EC has announced that it might review existing pieces of legislation to achieve climate neutrality by 2050.

Climate neutrality brings about major challenges for all economic sectors and for the European society as a whole. Europe will need to deploy all available technologies that can support a just transition in a cost-efficient manner. CCS and CCU technologies will, therefore, play a key role in the decarbonisation of especially industrial and energy sectors across Europe, enabling a just transition for European regions and citizens.

The urgent deployment of European CO2 infrastructure is also vital to unlock the benefits of CCS and CCU technologies and can deliver a safe, cost-efficient transition for European industrial and energy sector, while ensuring competitiveness and productivity levels. CCS and CCU, together with European CO2 transport and storage infrastructure, will also create new jobs along the CCS and CCU value chain, while maintaining those who are most exposed to climate change.

The activities proposed below should support ongoing work being undertaken in participating countries, which could involve a knowledge-sharing element to the proposals.

## *Industrial-scale deployment of CCS and CCU*

The need for early deployment of industrial-scale CCS projects remains a key priority for Europe. The level of deployment must be consistent with reaching net-zero GHG emissions by 2050 and the intermediate targets. Europe should enable the equal application of CCUS for all industrial sectors including process emission heavy sectors such as cement and steel.

- **Industry**: Adaption of current capture methods to new areas and development and deployment of higher RTL capture.
- **CCU**.
- The role of CCS in enabling **clean hydrogen**, including the role of blue hydrogen as bridging technology for the introduction of green hydrogen.
- The role, feasibility and scale of climate positive solutions (**negative emissions**), i.e. Bioenergy CCS and Direct Air Capture CCS.
- **Flexible Power Generation**.

For all these activities, the integration of CO2 transport and storage infrastructure is crucial to enabling decarbonisation and support for these activities should include relevant and appropriate studies of the required transport and storage infrastructure.

## *European CO2 infrastructure*

The development of regional CCS and CCU clusters and the development of European CO2 transport and storage infrastructure, that enables cross-border cooperation across all regions is crucial for the possibility to reach net-zero GHG emissions by 2050. CO2 infrastructure is deployable today and already operational in Europe, although challenges remain, why further R&I is needed. Recommended focus areas are:

***Projects of Common Interest (PCI)***

The importance of developing economic instruments that can support the deployment of CO2 infrastructure is critical. CEF/ Projects of common interest (PCI) remain a very important tool and should be updated as follows:

- The number of PCIs should be consistent with the development of regional CO2 infrastructure.
- PCIs should be extended to connecting also Member States without North Sea coastline to ensure that all regions with potential can plan CCS & CCU infrastructure.
- PCIs should utilise the full range of transport modality options, e.g. barge, ship and rail.

Reviews of infrastructure re-use (pipelines, wells, platforms from hydrocarbon industry) for transport and storage should identify those assets of strategic importance to PCIs and wider Member State plans for CCS.

***Map European CO2 storage assets***

A Europe-wide storage atlas will strongly support the strategic planning of activities to develop CCS. A “white paper” describing the benefits, intended users, functionalities and operation of the “European CO2 Geological Storage Atlas” was supported by IWG9.

We would recommend further exploring the use of big data and artificial intelligence.

***Support a European storage development/appraisal programme***

In line with a revision to the IWG9 Implementation Plan on CCS and CCU, a range of priority CO2 storage geological appraisal activities should be supported to ensure the required CO2 storage capacity is provided for the CCS deployment needed to achieve Europe’s decarbonisation targets. This should include:

- Appraisal of storage regions which would include pre-competitive evaluation of storage options to encourage subsequent commercial project uptake.
- Detailed characterisation of storage sites across Europe to define the *contingent storage resource* and to provide storage hubs for CO2 capture projects. This has strong links to the role of CCS in the energy system, described below, which will

determine possible scenarios of rates of CO2 capture at regional, national and European levels. This could include the testing of new formations to assess their feasibility for storage.

- Assessment of long-term and post-closure storage liabilities (technical risk and uncertainty) and the development of technical, regulatory, policy and commercial solutions.

***Map European CO2 sources/utilisation opportunities and longevity***

- CO2 sources and utilisation capacities across the EU should be assessed.
- Inventory of pre-commercial and/or industrial demonstration scale level CCU projects.

We would recommend further exploring the use of big data and artificial intelligence.

## *CCS and CCU Research*

Building industrial scale CCS and CCU projects will generate many new challenges that can best be solved by undertaking R&I in parallel with large-scale activities. An iterative process is needed where R&I projects address specific industrial challenges, with the results then implemented in large-scale projects. A recommended approach would combine existing datasets with specific analyses of industrial areas or plants, obtained by the use of artificial intelligence. Priority research topics include the following areas and are best addressed through R&I at a range of scales from laboratory to pilot scales:

*CO2 capture in industrial clusters*

- Integration and synergies with other sectors and renewable solutions.
- Process intensification – including utilisation of waste heat.
- Retrofitability.
- Part-load operation and flexibility.
- Buffer storage and shared transportation infrastructure.
- Treatment of waste products from capture plants.
- Degradation and life span of capture technologies.

*Cost reduction of CO2 capture*

- Lift innovative and particularly effective capture technologies from TRL5-6 to TRL 7-9.
- Modularization of capture technologies.
- Develop next generation capture technologies.
- Carbon removal technologies
- Fuel flexible combustion systems.

*Technological elements for capture and application*

- Flexible, modular and energy efficient capture and purification technologies considering specificities of the downstream application
- Capture and conversion integration and intensification for reduced energy consumption (including waste heat valorisation) and waste generation
- Novel and cost-effective materials (membranes, adsorbents, absorbents) with high durability and recyclability for increased capture rates.
- Catalyst and material development for conversion technologies into fuels and chemicals (electrochemical, photoelectrochemical, thermochemical).
- Increased uptake of CO2 during carbonation of primary and waste materials for the production of building materials (mineralisation).
- Increased direct uptake of CO2 for polymer production.
- Synthetic biology for increased conversion efficiencies in biological conversion and efficient downstream product processing.

*CCS and CCU transport systems*

- Value chain analyses (full chains, H2, ammonia and liquid organic H2 carriers).
- New CCUS chain concepts and transport networks (including hubs, buffers).
- Impact of CO2 composition and impurities.
- Safety assessments and engineering design tools.
- Non-pipeline transport of CO2 (e.g. ships, rail, trucks, etc.).
- Reuse of wells and platforms.
- Improved understanding of thermophysical properties of CO2 and CO2 mixtures.

*CO2 Storage*

- Develop experience with site conformance monitoring and assessment.
- CO2 flow behaviour near valves and chokes.
- Storage optimisation through development of a range of injection strategies including in highly depleted reservoirs.
- Cost-effective ways to repair legacy wells.
- New geophysical techniques for examining and characterising legacy wells.
- Great and deeper understanding of induced seismicity.
- Effective prediction of plume under geophysical and geological uncertainty.
- Storage of small volumes of CO2 and scale storage if needed.
- Dynamic storage capacity; understanding pressure responses, pressure-connected volume and pressure management techniques.
- Risk mitigation for storage value chain (financial, technical, regulatory).

*Standardisation and legislation issues*

- Provide data to include emissions from CO2 capture technologies.
- Standard CO2 specifications.
- Incentives for carbon negative solutions.
- Development of methods for measuring biogenic/fossil CO2 ratio.
- CO2 stream composition, including technical considerations such as pressure, temperature and physical state and MMV.

- Incentives for initiatives addressing a harmonization of legal standards / regulations relevant for the development of a European CO2 transport- and storage-network.

*Non-technological elements*

- Computational tools in process engineering & intensification (e.g. AI-driven process control, machine learning for catalyst development).
- Harmonised guidelines for life cycle sustainability assessment.
- Social acceptance of technology solutions towards achieving climate neutrality goals.

## *The contribution of CCS and CCU to reaching net-zero by 2050*

Analyses are needed on sector, Member State and EU level regarding how to enable Member States and the EU to reach net-zero emissions by 2050, including key technologies, milestones, etc.

CCS and CCU in the industry and Energy sectors in the Member States' National Energy and Climate (NECP), compatible with reaching net-zero by 2050. This is crucial in order to decarbonise Europe and should include the following elements:

- The national plans should be reviewed to ensure that they remain relevant to both Member States' and the EU processes and be updated in light of the European Green Deal and net-zero by 2050.
- The plans should include a relevant assessment of the role of CCS and CCU technologies to CO2 mitigation, including the contributions that clean hydrogen (green and blue with CCS), might make to decarbonisation of domestic heating, heat for energy-intensive industries, and for transport.
- The plans should also describe the Member State strategies and approaches to progress the deployment of CCS and CCU.