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RTD - Energy

ENER - Renewables, R&I, Energy Efficiency

JRC – Institute for Energy and Transport

SET Plan Secretariat



ISSUES PAPER No.9

Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)

Purpose of this document

This document¹ is intended to inform the discussions between the Commission, the Member States and stakeholders regarding the implementation of the actions contained in the SET-Plan Communication ("Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation" (C(2015)6317)), and specifically the actions concerned with the priority number 9 on CCS. It is part of a series of Issues Papers jointly prepared by the EC services. These documents will serve as a starting point for discussions with Member States and stakeholders in the development of new research and innovation cooperation at European and national level, especially as regards activities going beyond the Horizon 2020 programme. Each Issues Paper aims to define (a) the level of ambition (in terms of priorities and targets), (b) the modalities for the implementation and (c) the timing for achieving results and adopting expected deliverables.

Stakeholders are invited to take position on the proposed targets in accordance with the guidelines set out in the paper *The SET Plan actions: implementation process and expected outcomes* and submit their positions to SET-PLAN-SECRETARIAT@ec.europa.eu by **25 April 2016** at the latest. All relevant documents and material are available on the SETIS website <https://setis.ec.europa.eu/>.

Introduction – CCS and CCU

When assessing how to meet long term decarbonisation objectives, the Energy Roadmap 2050 as well as other reports have shown that fossil fuels might remain part of the global as well as of the European energy mix, not least because they will continue to be used in many industrial processes. CCS is at present one of the key promising technologies that can help reduce CO₂ emissions in the power generation sector and the only pathway for very stringent GHG emission reductions from specific energy and/or carbon intensive

¹This document is a working document of the European Commission services for consultation and does not prejudice the final form of any future decisions by the Commission.

industries that generate CO₂ as part of their production processes. In order to achieve the greenhouse gas emission reductions needed for keeping the global temperature rise this century well below 2 degrees Celsius as agreed at COP21 in Paris, CCS will need to be deployed from around 2030 onwards also in the fossil fuel power sector. For limiting this even further to 1.5 degrees Celsius, negative emissions may need to be achieved, e.g. by applying biomass conversion technologies with CO₂ capture and storage (Bio-CCS).

In order to realise its potential, CCS needs to become a cost-competitive technology and gain public acceptance (mainly regarding storage safety), so that it could start to be commercially deployed and thus contribute to the low-carbon transition of the European economy. The assessments made in the context of the EU's Roadmap for moving to a competitive low carbon economy in 2050 and the Energy Roadmap 2050 see CCS, if commercialised, as an important technology contributing to low carbon transition in the EU, with 7% to 32% of power generation using CCS by 2050, depending on the scenario considered. Furthermore, in these assessments, by 2035 CCS starts to contribute on a broader scale to reducing CO₂ emissions from industrial processes in the EU. [CO₂ conversion and reuse is also a relevant way to control CO₂ emissions.](#)
[Converting CO₂ in fuels and chemical compounds should be considered.](#)

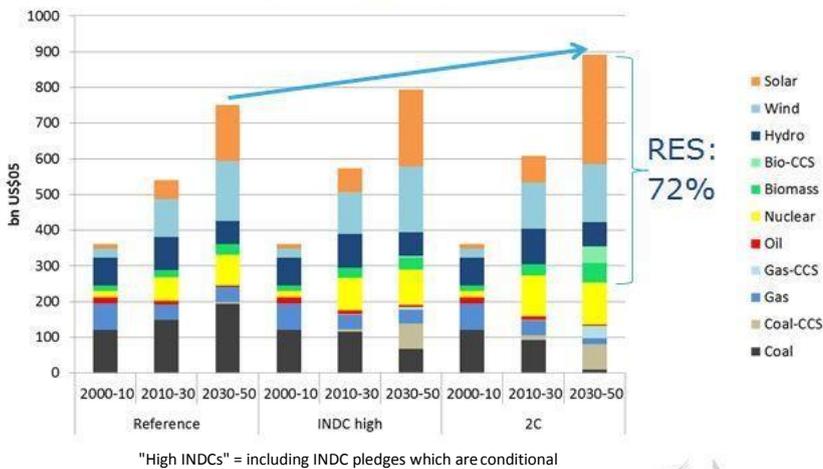
Why taking action now on CCS?

CCS has not yet taken off in Europe for a variety of reasons. However, the need for large scale demonstration, as a necessary step for its commercialisation and deployment, has not receded; on the contrary it has become more urgent. Commercial scale CCS demonstration projects are necessary in order to confirm CCS's technical and economic viability as a cost effective measure to mitigate greenhouse gases (GHG) in the power and industrial sectors. While CCS is not currently projected to significantly contribute to helping reach the EU's 2030 climate and energy targets and objectives, a "lock-in" into an energy infrastructure, which is not in line with the EU's long term decarbonisation objectives must be avoided. Failure to timely demonstrate CCS may therefore call into question new investments in fossil fuel power plants.

An analysis by the JRC (Global Energy & Climate Outlook, <https://ec.europa.eu/jrc/en/geco>) concludes that in case the 2° Celsius objective is taken seriously, most global investment in the power sector is expected to be renewables (see graph below), but average yearly investments of approximately US\$ 100 billion would be in coal and gas power plants with CCS:

Investments – power sector

World, average yearly investment



38



Without CCS demonstration projects in Europe, it could prove very difficult or even impossible to reach the agreed climate targets and the EU will not achieve technology leadership in this area and miss out on economic opportunities.

CCS is also necessary in carbon-intensive industries to reduce process emissions that cannot be avoided. Further delays may ultimately result in the need of the European industry to purchase CCS technology from non EU countries in the future. While purchasing CO₂ capture technologies is at least possible, this is not an option for establishing the necessary infrastructure for CO₂ transport and storage. Many of the existing upstream oil and gas infrastructure in the North Sea will be decommissioned in the coming years. Delaying CCS development would mean precluding possible synergies resulting in higher investment needs in the future. Also the market-penetration of possible fuels and other products from conversion of CO₂ (CCU) is a process which needs time and demonstrations should therefore be initiated as soon as possible.

Overall objectives and targets

The key technology-related objectives for CCS, both in the short and longer term, are to deliver the commercial-scale demonstration of the full CCS chain, and to reduce the costs of CO₂ capture through Research and Innovation. Demonstration will require maximising the use of strategic EU funds, especially the Innovation Fund, but also, if appropriate, the Connecting Europe Facility - CEF - and the Modernisation Fund. In particular, it will require establishing a reliable long-term business case for operating a CCS installation - based on a reformed Emission Trading System (ETS) but, if necessary, complemented by Member State support instruments. Last but not least, it requires increasing public awareness of the societal benefits of CCS and increased collaboration between EU Member States and Associated Countries.

The estimated overall availability of permanent geological storage capacity in Europe is equivalent to over 300 Giga tonnes (Gt) of CO₂². Total CO₂ emissions from EU power generation and industry are around 2.2 GtCO₂ annually. Therefore, there is no doubt that there are sufficient suitable storage sites to hold the CO₂ captured in the EU for decades to come. Storage capacity in the North Sea alone has been estimated at over 200 GtCO₂. The **detailed appraisal of storage capacity** in selected regions will be a key facilitator for commercial CCS deployment.

Comment [A1]: More accurate estimations of storage capacities is required hence the need for better mapping (see below in this paper)

While sufficient storage capacity exists in Europe not all capacity is accessible or located close to CO₂ emitters. Hence a cross border transport infrastructure is necessary to efficiently connect CO₂ sources to sinks. Under the regulation on "Guidelines for Trans European Infrastructure", CO₂ transport infrastructure projects can qualify to become **Projects of Common Interest** and can eventually be eligible for funding. Nevertheless, initially CCS projects will most often explore CO₂ storage sinks in the vicinity of capture points, hence infrastructure will first have to be developed at national level in order to become the nucleus of a **CO₂ hub that can develop into a cross-border network**.

Enhanced hydrocarbon recovery, especially enhanced oil recovery (EOR) combined with permanent storage is currently the only available large scale carbon capture and use (CCU) option which would actually remove relevant volumes of CO₂ permanently from the atmosphere. Also other CO₂ utilisation options for example as for fuel or for chemical compounds, could help improving the economic case for CO₂ capture, but further research & innovation activities are necessary for them to have a chance to make a meaningful contribution to our greenhouse gas reduction objectives and should therefore be intensified.

² <http://www.geology.cz/geocapacity>

Proposed key objectives and targets in CCS and CCU

By 2020:

- At least one commercial-scale CCS demonstration project operating;
- Completed feasibility studies on applying CCS to a set of clusters of major industrial CO2 sources (at least 3 clusters in different regions of the EU);
- At least one additional CCS demonstration project, preferably with an industrial source from which CO2 can be easily captured, having taken positive FID, which could be possibly funded from the part of the Innovation Fund available before 2021 (50 million allowances from Market Stability Reserve plus leftover money from NER300);
- **2025:** At least 1 Project of Common European Interest identified for CO2 transport infrastructure;
- An up-to-date atlas of the geological storage capacity that has been identified by various national authorities in Europe. This will provide additional certainty that the required CO2 storage capacity will be available when needed;
- **2025:** At least 3 pilots on promising new capture technologies, and at least one to test the potential of Bio- CCS and bio-CCU;
- At least 3 new CO2 storage pilots³ in preparation or operating in different settings;
- Completed feasibility studies for the use of captured CO2 for fuels and value added chemicals and products;
- **2025:** At least 4 pilots on promising new technologies for the production of value added chemicals from captured CO2;
- **2025:** Setup of 1 Project of Common European Interest for demonstration of different aspects of industrial CCU, possibly in the form of Industrial Symbiosis.

By 2025:

- At least 2 pilots on promising new technologies for the production of CO2-based mineral from CO2-capture or directly from flue gases
- At least 1 demonstration project featuring different aspects of industrial CCUS and renewables, possibly in the form of Industrial Symbiosis with local outreach

On the road to 2030:

- MS to deliver on their 2030 nationally determined contributions to the COP21 agreement, and in particular decide on the need for CCS to achieve these targets and make them compatible with the 2050 long-term emission targets;
- MS having prepared plans for retrofitting until 2040 at least 90% of their fossil fuel power plants capacity which they expect to be still operational beyond this date.
- MS having prepared, if appropriate in regional cooperation with other MS, feasibility studies for applying CCS in all major clusters of energy and carbon intensive industries in the EU by 2035, cooperating across border for transport and storing CO2.
- Further develop the potential of the industrial use of captured CO2, in particular through a Project of Common European Interest.

Comment [A2]: infrastructure could be dedicated to storage or utilization. At this stage, suggest not to mention a preferred location

Deleted: preferably related to storage in the North Sea

Comment [A3]: prior to establish an europeanCO2 storage Atlas, relevant methodology should be discussed. It is instrumental to implement CO2 storage pilot in the EU

Comment [A4]: among which at least one onshore pilot

Comment [A5]: we suggest adding mineral-based CCU because it has a significant emissions reduction

Comment [A6]: Synergies between bioenergy geothermal energy, renewable energy and CO2 capture, use and storage must be implemented and supported. The strong regional and local dimension of such projects will reflect the commitment of industries to the circular economy

³ Objective updated from the 'up to six new CO2 storage pilots' in the EII Implementation Plan (see Annex)

Some basic Key Performance Indicators			
	Metric	Target 2020	Target 2030
Levelised Cost of Electricity*			
Coal power plant with CCS (post-combustion / oxy-combustion)	€/MWh	70.2 / 66.4	68.2 / 63
NG power plant with CCS	€/MWh	87.4	84
Cost of CO2 avoided*			
Coal power plant with CCS (post-combustion / oxy-combustion)	€/t CO2	26.1 / 20.1	26.3 / 17.8
NG power plant with CCS	€/t CO2	45.3	40.5
Efficiency indicators			
Plant efficiency - coal with CCS (post-combustion / oxy-combustion)		35 / 37	35 / 39
Plant efficiency – NG with CCS		52	55
Average capture rate		85	95
Deployment indicators			
N° of demo projects with positive FID		2	15
Permits for CO2 storage		2	15
CO2 stored	Mt/yr	1	15

Comment [A7]: Add performance indicators for CCU as well

**Hard coal: €2.6/GJ, NG: €8.5/GJ; CO₂ transport and storage, and European emissions allowances not included; discount rate 8%; 85% load factor; lifetime: 40 years for coal, 30 years for NG; currency €₂₀₀₃ (data based on the EC report "ETRI 2014 – Energy Technology Reference Indicator projections for 2010-2050").*

Some recommendations on financing CCS demonstration and deployment

As regards early demonstration of CCS, the use of the ERA-Net instrument can be a useful tool to facilitate the pooling of the available funding from the EU and Member States to reach a critical mass. This should be considered in particular to enable first-of-a-kind CCS demonstrators.

For large-scale demonstration and deployment, which requires levels of funding surpassing the capacities of Member States and European Research Framework Programmes, the stakeholders (industry and Member States) should set up and agree on a list of potential CO₂ clusters or other projects of national, regional or common interest, which would also serve to prioritise the use of the existing or planned financial instruments like the Innovation Fund. Experience gained in commercial-scale CCS demonstration projects will also serve to prioritise research funding.

[Annex: Relevant actions of the 'Towards an Integrated Roadmap' document of the SET Plan](#)

Concrete targeted R&I actions for the long, medium and short term for CCS were proposed by stakeholders in the Annex 1 Part II Heading 4 of the 'Towards an Integrated Roadmap' document⁴. The headings of these actions are listed below. Priorities for future R&I actions will not least depend on the experience gained from commercial scale demonstration projects.

A. Proposed targeted R&I actions

Advanced Research Programme

1. CO2 Capture

Action 1: Basic R&D for supporting pilots and demonstration actions

Action 2: Proof of concept of efficient capture technologies for pan-industrial utilisation

2. CO2 Storage

Action 1: European ATLAS of potential storage sites

Action 2: Improved methods for site characterisation

Action 3: Improved methods for site monitoring

Action 4: Improved methods for safe storage exploitation

3. Competitive Carbon Capture and Storage (CCS) Value Chains

Action 1: Basic R&D and infrastructure for effective design and operation of CO2 transport systems

Action 2: Developing advanced materials for CCS applications and key enabling technologies

4. Conversion of CO2 from Process Flue Gases

Action 1: Advanced olefin production from CO2

Action 2: Demonstration of fine chemicals from CO2

Action 3: Access to competitive CO2 for chemical conversion

Industrial Research and Demonstration Programme

1. CO2 Capture

Action 1: Piloting of promising capture technologies

Action 2: Prove options to utilise the full potential of bio-CCS

2. CO2 Storage

Action 1: Start-up and management of up to six new CO2 storage pilots

3. Competitive Carbon Capture and Storage (CCS) Value Chains

Action 1: CO2 transport pilots for effective design and operation of CO2 transport systems

Action 2: Efficiency improvement and key enabling technology development for CCS

4. Conversion of CO2 from Process Flue Gases

⁴ https://setis.ec.europa.eu/system/files/Towards%20an%20Integrated%20Roadmap_0.pdf

Action 1: Demonstration of industrial scale production of polymers from CO2

Action 2: Demonstration pilot for mineral production from CO2

B. Framework conditions - policy measures

Innovation and market-uptake programme

1. CO2 Storage

Action 1: Start-up and management of CO2 storage demonstration projects

2. Competitive Carbon Capture and Storage (CCS) Value Chains

Action 1: Pan-European transport of CO2

Action 2: Develop tools for understanding integration and cross-cutting issues

Action 3: Demonstrate Large Scale Integrated CCS plants

3. Conversion of CO2 from Process Flue Gases

Action 1: CO2 based products should be recognized as renewable products and benefit from appropriate support

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