European Power Plant Suppliers Association
Developing the Future

EPPSA input paper to European Commission Issues Paper 9

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RTD - Energy

ENER - Renewables, R&I, Energy Efficiency
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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 document[1] is intended to inform the discussions between the European 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 the European Commission, 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/.

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

Introduction – CCS

When assessing how to meet long term decarbonisation objectives, the Energy Roadmap 2050 ~~as well~~and ~~as~~ other reports ~~have~~ all shown ~~that~~ fossil fuels ~~might~~ will remain part of the global ~~as well as of the~~and European energy mix for the foreseeable future~~,~~ due to their continuing need ~~not least because they will continue to be used in~~ for power generation and other ~~many~~ industrial processes~~and power generation processes~~. CCS is ~~at present~~ one of the key ~~promising~~ technologies ~~that can~~for ~~help~~ reduc~~e~~ing CO2 emissions in the power generation sector and the only pathway available for very stringent greenhouse gas (GHG) emission reductions from specific energy sources and ~~other/or~~ carbon intensive ~~high CO2 emitting~~ industries.

~~industries that generate CO2 as part of their production processes.~~ ~~I~~In order ~~t~~o achieve the ~~greenhouse gas~~GHG emission reductions needed ~~for~~ to ~~keeping~~ limit the average global temperature rise this century to ~~well~~ below 2 degrees Celsius as agreed at COP21 ~~in Paris~~, CCS will need to be deployed as soon as possible ~~from around 2030 onwards~~ across the industrial and power generation sectors ~~also in the fossil fuel power sector~~. And to ~~For~~ limit~~ing~~ the average global temperature rise ~~this~~ even further to~~and to~~achieve the aspirational target of below 1.5 degrees Celsius, negative emissions will conceivably ~~likely~~may be required~~needed to~~

~~be achieved, e.g.~~ by applying biomass conversion technologies in combination with CO2 capture and storage (Bio-CCS) in thermal power generation plants.

~~In order to realise its potential~~For commercial deployment and the low carbon transition of the European economy, CCS needs to become a more cost-competitive technology ~~and~~ with~~gain~~ full public acceptance of ~~(mainly regarding~~ underground CO2 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~~ once commercialised, as an absolutely necessary ~~important~~ technology ~~contributing~~ for the transition to a low carbon ~~transition in the EU~~Europe. The assessments see~~, with~~ a minimum of 7% ~~to 32%~~ of power generation using CCS by 2050 rising to 32% depending upon the possible ~~the~~ scenarios considered. ~~Furthermore, i~~In these assessments~~,~~ by 2035 CCS is also seen ~~starts~~ to be starting to contribute ~~on a broader scale~~ to reducing CO2 emissions from industrial processes ~~in the EU~~.

Why taking action now on CCS?

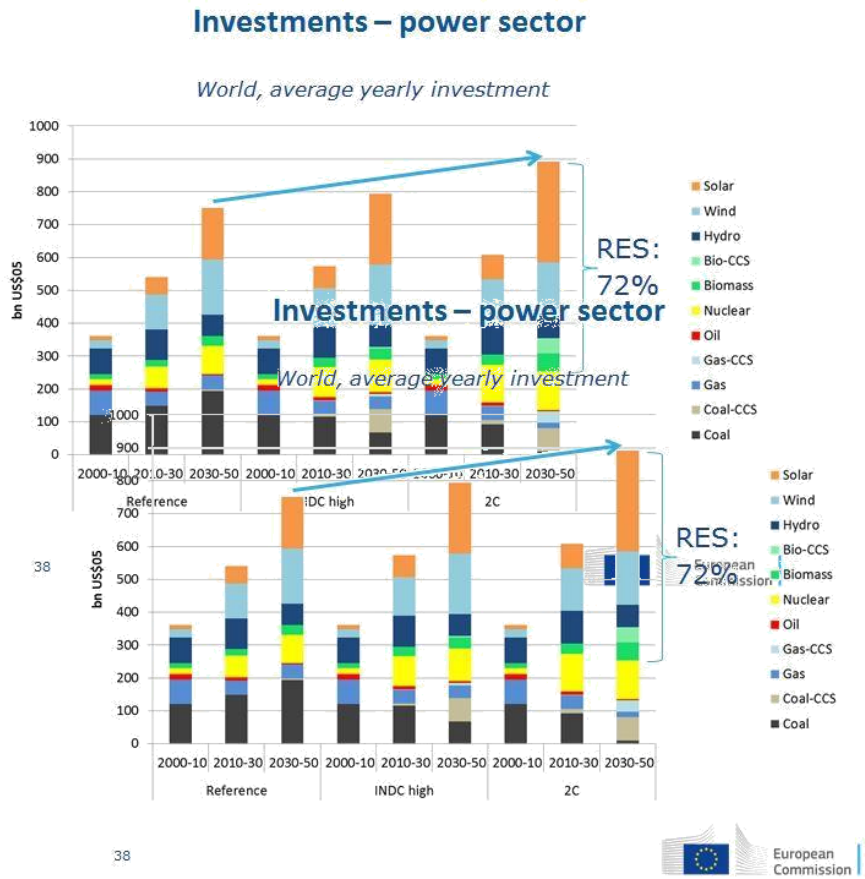
CCS has not yet ~~taken off~~reached the point of being commercially available in Europe for a variety of reasons, the most significant being the low price of EU Emission Trading System (ETS) allowances, as well as the lack of market incentives and ~~lack of~~. ~~However, the need for~~ a large scale demonstration, which is now becoming ~~, as a necessary step for its commercialisation and deployment, has not receded; on the contrary it has become more~~even more urgent. Many technology suppliers have their technology ready and piloted, but these are suffering inexistent market conditions for the uptake of this technology. This plays, for example, as an obstacle for investing in modern state-of-the-art efficient low-carbon fossil fuels based power generation. Commercial scale CCS demonstration projects are therefore necessary ~~in order~~ to confirm

Commented [FP1]: EPPSA comment: We should not delay support to CCS deployment until 2030. All efforts should be made to achieve full deployment as soon as possible. The later the introduction of CCS, the more costly and demanding this will be.

Commented [FP2]: EPPSA comment: Incentive schemes for low-carbon energy technologies and further reduction of the cost of CCS are needed to allow these technologies to compete with unabated energy technologies and ultimately attract investment and market uptake.

Commented [FP3]: EPPSA comment: CCS is already commercially available. The question is not if it should be commercialised, but when.

Commented [FP4]: EPPSA comment: The only financial instrument to incentivise the deployment and operation of low carbon technology like CCS has been the ETS. In comparison, the deployment of Solar and Wind energy sources has benefitted from direct subsidies, ensuring bankability for investors. Proper incentive schemes and support should be considered.



CCS's technical and economic viability as a reliable and cost effective ~~measure~~ solution to mitigate ~~greenhouse gases (~~GHG emissions~~)~~ ~~in~~ across the power generation and industrial sectors.

~~While~~ CCS is also 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 risks calling into question ~~new~~ needed investments in modern efficient state-of-the-art fossil fuel power plants, which will be prepared ~~suitable~~ for CCS, and carbon intensive industries. This situation would likely have deterrent consequences for the European economy and the environment.~~.~~

Commented [FP5]: EPPSA comment: How a lock-in can be avoided for long-term investments that require long term amortisation? This part also does not link with the rest of the sentence. Suggest to delete it.

Commented [FP6]: EPPSA comment: CCS equipped power plants are a key part of the lowest cost solution to mitigate GHG emissions and tackle climate change.

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~~followed, most global investments in the power sector is expected to be renewables (see graph below), while ~~but~~ average yearly global investments of approximately US$ 100 billion would be in coal and gas power plants with CCS:

"High INDCs" = including INDC pledges which are conditional

CCS is also necessary in carbon-intensive industries to reduce ~~process~~ emissions that cannot be avoided. Without a CCS demonstration project~~s~~ in Europe, it ~~could~~ will ~~therefore prove~~ be very costly, difficult or even impossible for Europe to reach the agreed climate targets. Furthermore, c~~and there is no c~~hances of the EU ~~will not~~ achieving~~e and/~~or maintaining technologically~~ leadership in this area with potentially huge ~~and miss out on~~ economic opportunities will be lost to the US and Asia as ~~.~~

~~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 will have no option other than to purchase CCS technology from ~~non EU countries~~elsewhere ~~in the future~~. While purchasing CO2 capture technologies ~~is~~ will at least be possible, this ~~is~~ will not be 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 for example precluding possible synergies in existing industrial and power generation infrastructures in the North Sea resulting in higher increased investment needs in the future.~~ Also the market-penetration of ~~possible~~ fuels and other valuable products from conversion of CO2 (CCU) is a process which needs time, so the~~and~~ earlier these~~-~~ demonstrations ~~should therefore be~~are initiated the better. Furthermore, the concept of conversion of CO2 into other products is fully aligned with the EU Circular Economy Strategy (COM(2015) 614 final).

Commented [FP7]: **EPPSA comment**: unclear meaning. Please clarify or delete. Considering potential synergies with existing industrial and power generation infrastructures should also be envisaged.

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 reliability and full operational flexibility of CCS chains, and to reduce the costs of CO2 capture through Research and Innovation. Achieving the uptake of CCS~~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 EU E~~mission T~~rading ~~System (ET~~S~~)~~ but, if necessary, complemented by ~~Member State~~national support instruments and adjustment of the regulatory framework. 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 development of the capture technologies has already been successful and will continue to be in the future as there is no technical show -stopper. Storage capacity is key for the development and deployment of CCS and this topic should get the highest priority. The estimated overall availability of permanent geological storage capacity in Europe is equivalent to over 300 Giga tonnes (Gt) of CO2[2]. 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.

While sufficient storage and utilisation 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 – such as the conversion of CO2 into chemicals (especially low-carbon fuels) - could help ~~improving~~ improve the economic case for CO2 capture as well as provide a cross-sectoral decarbonisation path for e.g. the transport sector. Besides improving the economics of CO2 capture, certain CCU options also provide a mean for the permanent sequestration of CO2. That is the case, for instance, when using CO2 as the solvent for EOR, and in the emerging technologies of carbonation and mineralization from industrial processes, where sufficiently reactive residues are permanently bound with CO2 to form valuable materials. If some of those technologies have already reached higher TRLs, ~~but~~ further research ~~&~~, innovation and mostly demonstration activities are necessary for them to have a chance to make a meaningful contribution to our GHG~~greenhouse gas~~ emissions reduction objectives and should therefore be intensified.

The utilisation/conversion of CO2 properly integrated with permanent CO2 storage options will enable the development of common CO2 infrastructures, provide system flexibility by demand response of CCU applications and provide a reliable CO2 source for emerging CCU technologies with smaller CO2 off-take levels.

[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/CCU to a set of clusters of major industrial and power generation CO2 sources (at least 3 clusters in different regions of the EU);
- At least one additional CCS/CCU demonstration project, preferably with an industrial or power generation 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);
- At least 1 Project of Common European Interest identified for CO2 transport infrastructure, preferably related to storage in the North Sea;
- 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;
- At least 3 pilots on promising new capture technologies, and at least one to test the potential of Bio-CCS;
- At least 3 new CO2 storage pilots[3] in preparation or operating in different settings;
- Completed feasibility studies for the use of captured CO2 for fuels and value added chemicals;
- Completed FEED studies for CCU projects, 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);
- At least 4 pilots on promising new technologies for the production of value added chemicals from captured CO2;
- Setup of at least 1 Project of Common European Interest for demonstration of different aspects of industrial CCU, possibly in the form of Industrial Symbiosis.

On the road to 2025

- Further investigations on the atlas of the geological storage capacity with regard to storage feasibility and social acceptability
- At least one commercial-scale CCS/CCU demonstration project operating;

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/CCU to achieve these targets in ETS and non-ETS sectors 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

Commented [FP8]: **EPPSA comment**: This objective would need immediate commencement of the project, i.e. not realistic. Moved below to suggested point for 2025

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

applying CCS/CCU in all major clusters of energy generation 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.

Commented [FP9]: **EPPSA comment**: Too late. Feasibility studies should be available much earlier. This point may need to be moved up to better reflect the need for actions as soon as possible.

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

**Hard coal: €2.6/GJ, NG: €8.5/GJ; CO_2 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").*

Commented [FP10]: EPPSA Comment:
1.Cost of electricity, cost of CO2 avoided and efficiency indicators are not fully suitable for first generation, but adequate for second generation oxy-fuel plants. However, second generation oxy-fuels plants cannot be targeted for 2020. 2025 or even 2030 is a more realistic target. Figures in the table should be amended accordingly.
2. Can the European Commission confirm that all these KPI and associated figures are from the EC report ETRI 2014? If not, what is the source and is it reflecting the views of the sector?

Some recommendations on financing CCS/CCU demonstration and deployment

In order to overcome existing challenges linked to CCS/CCU demonstration and deployment (e.g. the large amounts already spent on R&D, inexistent market conditions, CCS operational costs) public funding will need to be increased, without prejudice to the funding necessary for other R&I priorities in the energy system (e.g. other SET-plan actions and associated priorities). ~~As regards early demonstration of CCS/CCU, t~~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 support early demonstration of CCS/CCU and reach a critical mass. The latter instrument~~is~~ 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/CCU demonstration projects will also serve to prioritise research funding.

SET Plan Secretariat – 05 April 2016

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/CCU were proposed by stakeholders in the Annex 1 Part II Heading 4 of the 'Towards an Integrated Roadmap' document[4]. 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, including for Bio-CCS

Action 2: Demonstration ~~Prove options to utilise~~of 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**

Commented [FP11]: EPPSA Comment: This may be a need for industrial applications. For the power sector, extensive piloting has been done already on CO2 capture. What is needed now is to move on with the solutions that have been already demonstrated at mid-scale level. There is a need to focus funding on demonstrations in commercial scale for those solutions that have already proven viability in pilots and mid-scale demonstrations.

Commented [FP12]: EPPSA comment: This wording might be confusing and it is not clear if we refer to industrial sector (as opposed to power generation sector) or if this refers to the scale of the programme, i.e. large scale. In the future, perhaps a clearer wording should be chosen to avoid any confusion and unintended exclusion of any sector.

Commented [FP13]: EPPSA Comment: Same comment as above under Advanced Research Programme, point 1. CO2 Capture

[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 valuable materials ~~mineral~~ production from CO2

Action3: Demonstration of large-scale production of chemicals and fuels

Commented [FP14]: EPPSA comment: Although mineralisation may appear the most promising option today, there is no reason to deny that other options for CCU may become more appealing (progresses in this field are rapid).

B. Framework conditions - policy measures

Innovation and market-uptake programme

Commented [FP15]: EPPSA comment: a review of the regulatory framework to drive efforts in CCS deployment may also be needed

1. **CO2 Storage**

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

Action 2: develop an enabling framework for the development of CO2 Transport and Storage on a commercial basis

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/recycled products and benefit from appropriate support

Action 2: CO2 converted into other products should be – similarly to the CO2 stored – recognized as non-emitted.

Public acceptance

Action 1: Deployment of awareness/information campaigns on the benefits of CCS/CCU and of CO2 based products, as well as associated safety, with the support and coordination of the European Commission.