To: The SET Plan Secretariat
Att: Karina Firkaviciute

EERA JP CCS
Att: Dr. Marie Bysveen
(Coordinator EERA JP CCS)

Trondheim, 2016-04-25

Response to the SET Plan Issues paper No. 9 – CCS/CCU

Dear Mrs Firkaviciute

Many thanks for the opportunity to comment on the Draft Issue Paper for CCS and CCU.

This document gives the viewpoint of EERA JP CCS on the *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)*. EERA CCS JP represents 39 large research organisations across Europe with an active research programme on CCS.

We welcome this Issues Paper, which clearly addresses the need for CCS. CCS is strongly needed and the importance of CCS is even strengthened after the COP21. The Issues Paper is a good starting point for wide scale commercial deployment of CCS in Europe.

Do you agree with targets set in the issue paper?

1. ***Main objective of the process***: We note that this paper is the starting point for discussions with MS and stakeholders. However, a statement as to the ultimate objective of the whole process should be made. We propose the following main objective: *To enable the SET Plan Steering Group to agree on priority actions towards large scale deployment of CCS by 2030, in accordance with the SET Plan.*
2. ***Long-term objective for CCS***: The overall objective (to *demonstrate* CCS) is short term and we propose the following long-term objective: *Wide-scale commercial deployment.*
3. ***Sub-objectives/targets***: We believe more descriptive targets are more appropriate in gauging progress than specific quantitative targets for power plant efficiencies. Gains in efficiency, whilst reducing costs, will not enable deployment of CCS if not combined with other urgent actions. We propose the following descriptive targets:
    a. Implementation of a reasonable number of commercial scale CCS projects to enable 'learning by doing'.
    b. Definition of a legal framework and of market/funding schemes to enable private investments.
    c. Gain public acceptance of CCS through targeted R&I , pilot and demonstration projects – particularly related to transport and storage.

4. ***Relevance, quality and number of KPIs:*** There are too many KPIs, many of which will not allow appropriate monitoring of progress towards the objectives. For example; A 20% reduction in LCOE is not what will deliver CCS. The 'proof of the pudding' is CO_2 stored away from entering the atmosphere. Indicators of CCS deployment would be more useful. KPIs should include scale of investment, including the number of Member States needed to come together to produce demos.
5. ***Clusters***: With reference to 'Completed feasibility studies applying CCS to a set of clusters of major industrial CO_2 sources (at least 3 clusters in different regions of the EU)…" Delete word 'industrial' as the clusters can be a mix of emitters. This is an achievable target but should be even more ambitious in terms of timing towards 2020. Target should be 5-7 clusters across whole of Europe.
6. ***CO_2 storage*** : There is not enough progress described for CO_2 storage (table on page 5);
    a. Objectives are missing to create bankable storage capacity and the Issues Paper does not recognize the work being done in a number of countries (especially Norway, Netherlands and UK) on detailed site appraisals for storage. A storage atlas is very important but not sufficient for developing commercial projects. EU should provide through targeted R&I action sufficient information on transport and storage to enable commercial developers to make sound judgements of options for T&S. The detailed information will have to be assembled by project developers and the relevant MS for instance through PCIs.
    b. There should be an additional bullet, for 'a portfolio of storage sites (2-5 sites with potential for cluster development as CO_2 capture increases) close to permitting for storage ('bankable storage'), with a combined storage capacity that is sufficient for the first two decades of storage'.
    c. The storage target for 2020 is too low as we are already storing ~2 Mt CO_2 /yr at Sleipner and Snohvit. A more representative target would be at least 3 Mt/yr.
    d. Work has been done that indicates that cost-reductions may also be found in storage, especially where strategic management of clusters and larger stores can be achieved.
7. In the area of ***CO_2 capture***, key concerns include:
    a. CO_2 capture costs and long term process efficiency
    b. Lack of funds and incentives for developing technologies for industrial and bio-CCS applications.
    c. Lack of understanding and technology readiness for coping with highly intermittent and flexible operation of plants equipped with CCS.
8. ***CO_2 value chains***: Transport and storage infrastructure requires specific actions because there are upfront storage appraisal costs and commercial structures needed for storage provision. Issues include:
    a. Risks sharing between parts of the CCS chain
    b. Storage liability costs and liability sharing
    c. Creating portfolio of permitted storage
    d. Establishing least cost CO_2 transport routes with redundancy to developing knowledge of available CO_2 storage capacity
    e. Regulations and liability policies to address commercial storage issues
9. ***R&I Actions proposed***: Although the nature of the R&I actions proposed is good, they benefit from reformulations, see Annex I.

Do you think that the level of ambition is correct?

1. ***Ambitions and associated funding***: The targets are very ambitious and must be followed by significant funding.
2. ***Least cost routes to 2DS***: IPCC (AR5) and IEA (ETP, WEO) clearly show that least cost routes to achieving the 2 degree target is by including CCS. This should be better reflected in the text. Fossil fuels are *very likely* to remain part of energy mix and thus CCS in needed.
3. ***Initiate CCS deployment***: Do not imply a need to demonstrate CCS now, but the need to initiate CCS deployment. Initial deployment will identify issues where further R&I is required, fex to improve cost-effectiveness. Commercial-scale integrated CCS projects are in successful operation outside Europe.
4. ***Legal requirements like Emission Performance standards (EPS)*** are likely to be required to make CCS happen at a pace and volume needed.

Are there any standing issues in the way to reaching the proposed targets/priorities?

1. ***What is critical now*** is concrete policy, financial and strategic planning actions to enable infrastructure and development of clusters.
   a. F.ex., regional infrastructure must be enabled by 2025 or 2030, between some countries.
   b. Regulation and/or robust policy measures (EPS) to enforce the implementation of CCS is fundamental to making a successful business case for CCS.
2. ***No sense of urgency***: Introduction of CCS starts very late according to this document. Deployment should as soon as possible to enable European and global emission targets (COP21).
   a. There must be targets and actions between now and 2030 to enable CCS to progress.
   b. Given ongoing global activity, we propose to move away from suggesting a need to demonstrate CCS, and move towards recognising the need to build 'catalysing' projects and supply chains.
3. ***Technology R&D*** is continuously needed to: Improve processes, reduce cost, remove barriers, increase integration of CCS and CCU with the rest of the energy system, etc.
4. ***Barriers to deployment***: The lack of investor confidence, lack of bankable storage and perceived costs are barriers which should be addressed.

What are your specific recommendations on prioritizing R&I activities on these issues (and building where appropriate on relevant existing initiatives)

1. ***Deployment of CCS*** in Europe is key for further development.
2. ***Deployment and supporting R&D program***: The realization of demo-projects with supporting R&D programmes is essential. For example, the ROAD project currently offers an opportunity to generate further developments both on a high and low TRL level.
2. ***Fundamental research*** into the different parts of the CO2 value chain is strongly needed considering that 2nd gen commercial scale CCS plants will be implemented from around 2030. These plants / transportation grids / storage sites will need to be commercially competitive. Thus, technology and processes need to be optimised further.
3. ***CO_2 Capture***: Development and piloting of low cost capture techniques for industrial application are the next step to quickly address the high CO_2 emissions from several industrial sectors.
4. ***Bio-CCS***: A R&I programme to accelerate development and deployment of bio-CCS technologies is very important in order to reduce cumulative CO_2 in the atmosphere.

5. ***Integrated hydrogen, renewable and CCS concepts***. There is an urgent need to see these in conjunction as they may share infrastructure and will provide more effective solutions. One example is hydrogen for large scale natural gas/coal reforming/gasification with CCS, this will provide hydrogen to the industry sector and for low emission mobility.
6. ***CO_2 storage***:
    a. New storage pilots should be targeted to solve scientific questions and to address investor and public concerns. They should aim at undertaking test injections to prove capacity and injectivity with extended well testing to create bankable storage. This could be focused at existing or near-term storage options, and could thereby act as catalysts for full-scale deployment. This should include offshore tests.
    b. Other barriers include pressure management options.
7. ***CO_2 transport clusters***: The development of clusters being effective in gathering CO_2 from multiple sources and that ensure access to bankable storage is important. R&I to support these developments could consider options for liquid CO_2 transport on ships and further work on the effects of minor components in CO_2-rich mixtures (particularly those that may arise from more challenging CO_2 sources such as biomass and some industrial emitters).
8. ***CCU should be addressed***, but the focus should not be short term demonstration. At this point in time CCU can hardly contribute to avoid further global warming and will probably not be profitable (except for EOR – demonstration of EOR with captured CO_2 makes sense already at short term). We therefore recommend fundamental research on advantageous solutions for CCU for beyond 2030. Hydrogen from fossil fuels with CCS should be regarded as part of the CCU concept- creating many options for widespread use.

Who are the best placed actors to implement the targets/priorities (industry, EU, Member States, regions, group of countries/organizations/etc.)?

1. ***Actors***: A number of actors are needed and include those listed. EERA CCS JP, alongside the European Technology and Innovation Platform (ETIP) ZEP, can play a major role in coordination and facilitation of future collaboration between MS, EC researchers and commercial project developers and their investors.
2. ***Joint effort***: CCS deployment should be a joint effort between Industry, EU, Member States and regions. It is not possible for a single nation, nor a single industry to start a demonstration project because the initial costs are too high and the industry/power company experiences higher operational costs. Regions should also be involved, not only because the financial contribution, but also because the public in the region will benefit from and have to deal with CCS. The same applies for some of the pilot projects.

We have also provided detailed comments on the text in the Annex.

Yours sincerely,

EERA JP CCS

Marie Bysveen

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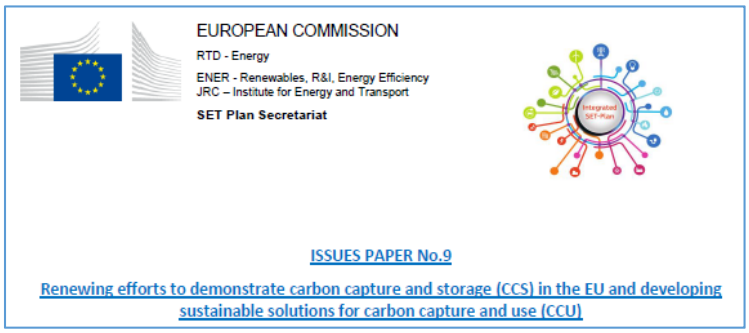
ANNEX I - Detailed comments on specific text

Here we comment and propose corrections to specific text where we disagree or seek further clarification.

1. Heading (p.1)



EUROPEAN COMMISSION

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)

Comments:

1.a. We propose the title should be:

Renewing efforts to deploy carbon capture and storage (CCS) in the EU

2. Purpose of this document (p.1)

Purpose of this document

This document[1] 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/.

No further comment – all comments made above in response to specific questions.

3. Introduction – CCS (p.1&2)

Introduction – CCS

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

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.

Comments:

3.a. In the 2nd paragraph, we propose: *'CCS needs to become a cost-competitive technology by 2030*'.

3.b. With reference to lines 8/9 and 16-18 not consistent. Lines 8/9 state: *"… around 2030 onwards also in the fossil fuel power sector…"* Not clear to what "also" refers here. Referring to lines 16-18, lines 8/9 should be rephrased to "… around 2030 onwards in the fossil fuel power sector and also carbon intensive industries."

3.c. With reference to line 4: *"…key promising … that can help …"* is a too weak statement and does not adequately reflect the role that CCS need to play.

4. Why taking actions now on CCS ? (p. 2)

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:

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.

Comments:

4.a. With reference to Page 2, first paragraph: The Issues Paper should recognise that North America has made substantial progress in CCS and Europe risks becoming less competitive as a result of inaction.

4.b. We propose proactive and stronger links including collaboration with US and Canada firstly, and Asia and Australia secondly. European researchers should learn from experience in these leading countries to improve the global alignment of research / development and innovation agendas.

4.c. Suggest more on the coupling between CCUS and RES & H_2: Could mean a lot for the public perception. Link to other relevant Issues papers. CCUS is not 'a single island' in the Integrated Energy System.

4.d. With reference to 3rd paragraph, lines 2/3: Delay may not only result in need to purchase CCS technology from abroad but lack of economic CCS solutions for carbon-intensive industries may also reduce their international competitiveness.

4.e. With reference to the 2nd paragraph, last sentence: The proposed demonstration projects will not deliver enough storage to reach our climate targets. The implementation of CCS at an industrial scale is the pre-requisite for reaching the targets and initial commercial-scale deployment is the first step.

4.f. With reference to the 3rd paragraph. We propose adding to the last sentence "*…as soon as possible for projects demonstrating a net avoidance of CO_2 emissions."*

5. Overall objectives and targets (p. 3)

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 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 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 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.

Comments:

5.a. Too much focus on coal and power plants. Should be more on natural gas and industry and also on carbon negative solutions.

5.b. Should include flexibility and integration -focusing on overall integrated energy system, including integration with RES.

5.c. With reference to Page 3, last paragraph: '..based on a reformed Emission Trading System (ETS) but, if necessary, complemented by Member State support instruments': We suggest that recent experience has shown that MS support is likely to be mandatory to support initial CCS deployment, especially for transport and storage.

5.d. With reference to Page 3; Third paragraph: "…CO_2 transport infrastructure projects can qualify to become Projects of Common Interest and can eventually be eligible for funding…". This wording is too passive. We propose: "PCIs should be pursued as a vehicle for developing an effective Pan European network for transport and storage".

5.e. With reference to Page 3: fourth paragraph: "… 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 CO_2 permanently from the atmosphere…" However, life-cycle analysis indicates overall CO_2 reductions are not large. R&D therefore needed to improve this. EOR may be a way to offset some of costs.

5.f. With reference to Page 4, second paragraph: '… Nevertheless, initially CCS projects will most often explore CO_2 storage sinks in the vicinity of capture points, hence infrastructure will first have to be developed at national level…" We disagree with this assertion and we believe this is the wrong assumption. Transport and storage has to be dealt with as a European infrastructure, initiated in a regional context based on national interest. Furthermore, the text states *"… to become the nucleus of a CO_2 hub …"*, the proposed/assumed national simple source-to-sink CCS projects may turn out to be isolated projects in no way suitable to serve as nucleus for a later CO_2 hub. The potential to serve as nucleus should be a high-level criterion in evaluation, prioritizing and funding of proposed initial projects.

5.g. With reference to Page 4, last paragraph: "..Also other CO_2 utilisation options could help improving the economic case for CO_2 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…" This is clearly thermodynamically unhelpful and will not make a meaningful contribution to climate change. However it is useful for future circular economies and for displacing fossil fuels; this should be made explicitly clear.

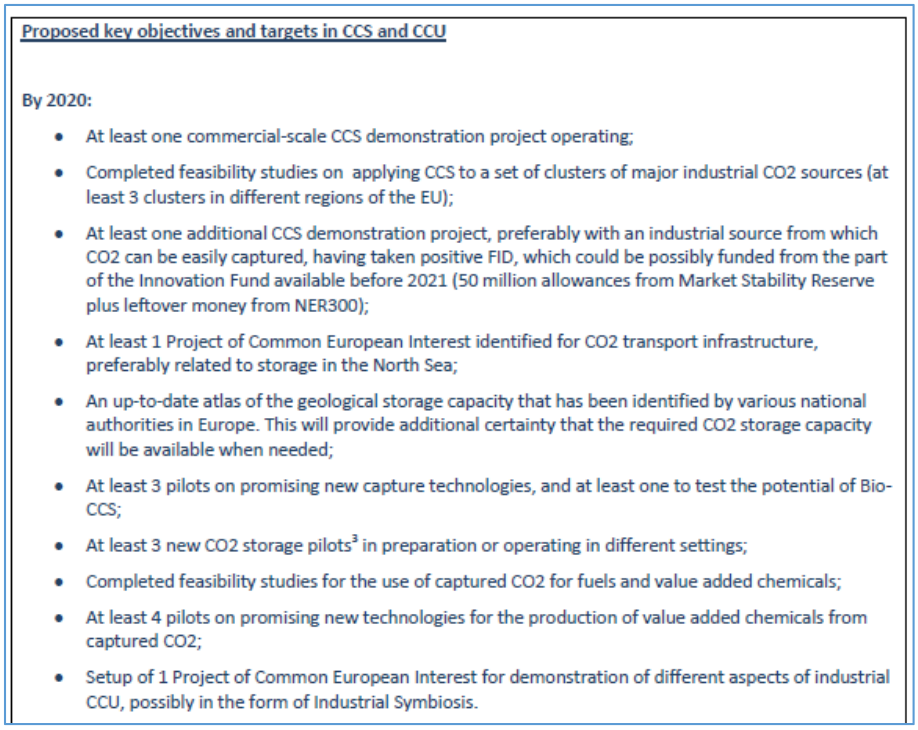
5.h. With reference to 2nd paragraph, last two lines: "…*The detailed appraisal of storage capacity …*". Storage appraisal by itself is insufficient and will not facilitate CCS deployment. We need such an appraisal for whole Europe but the development of bankable storage sites for selected regions to facilitate cluster development and cost savings. This development of bankable storage is likely to require at least some funding through public money.

5.i. With reference to 4th paragraph, the last sentence we propose to change the last sentence to *"…should therefore be considered."*

5.j. CO_2 transport infrastructure should also consider ship transport, either as an independent solution or ideally integrated into a hub concept.

5.k. Regarding the role of CCU: We propose to prioritise CCS now for R&D, and to include low TRL CCU for future R&D to increase CO_2 reductions in future.

6. Proposed key objectives and targets in CCS and CCU – By 2020 (p. 5)



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);
- 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;
- At least 4 pilots on promising new technologies for the production of value added chemicals from captured CO2;
- Setup of 1 Project of Common European Interest for demonstration of different aspects of industrial CCU, possibly in the form of Industrial Symbiosis.

Comments to 'By 2020':

6.a. With reference to "At least one commercial-scale CCS demonstration project operating…"; Remove the wording 'demonstration'.

6.b. With reference to: 'At least one additional CCS commercial project, preferably with an industrial source from which CO_2 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); Again avoid specifying industrial source. Will there be sufficient funding to achieve this goal? Another option would be to fund a number of FEEDs to create a portfolio of options when significant funds become available. Avoid specifying types of emitters – just aim for the cheapest options in a given area. An alternative use of the funds (proposed by CCSA) would be to undertake a larger number of cheaper FEED studies to create a portfolio of options, from which projects can be selected as more funding becomes available.

6.c. One infrastructure project may be insufficient. Scenarios can be very different, depending on how many sources of which size are involved and whether ship transport is involved or not, … and we therefore propose that to develop confidence for widespread rollout a larger number of sufficiently different infrastructures is likely to be required.

6.d. With reference to: "…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 CO_2 storage capacity will be available when needed…" We regard this as an easy objective because LCE26-2016 is already addressing this. Whilst it is a useful step,

providing a portfolio of bankable (permit-ready) storage options is needed and will require further work. The challenge will be developing a methodology that allows comparisons when estimates are based on different data qualities. We propose that the wording should be '…an up-to-date and mutually accepted atlas…'

6.e. Objectives are missing to create bankable storage capacity and the Issues Paper does not recognize the work being done in a number of countries (especially Norway, Netherlands and UK) on detailed site appraisals for storage. A storage atlas is not enough for building confidence in available storage space. It does not tell you where the pipeline should go nor does it fully ||leverage the progress already made at a number of strategic future stores (e.g. 'Endurance' in the UK SNS or P18 in Dutch SNS). There should be an additional bullet, for 'a portfolio of storage sites (2-5 sites with potential for cluster development as CO_2 capture increases) close to permitting for storage ('bankable storage'), with a combined storage capacity that is sufficient for the first two decades of storage'.

6.f. With reference to *" At least 3 pilots on promising new capture technologies, and at least one to test the potential of Bio-CCS…"* The scale and TRL for these pilots should be defined, i.e. the number of tons CO_2 captured. This is considered to be challenging and will require to gear up efforts. This is crucial – but not a KPI. Not clear whether one out of three has to be Bio-CCS or are four pilots (with at least one Bio-CCS) asked for.

6.g. Same table, second section, 'On the road to 2030': add

- 'Market maker(s) or policy measures for transport and storage identified in MS' '
- MS preparing further bankable storage capacity, to provide storage space for the next wave of capture projects'

6.h. Research should also be focussed on cost-reduction as this is still a requirement.

6.i. With Reference to: "…*At least 4 pilots on promising new technologies for the production of value added chemicals from captured CO_2*…". This and the following objective gives too much weight on this route which is not relevant for fighting global warming- must be scaled according to possible role.

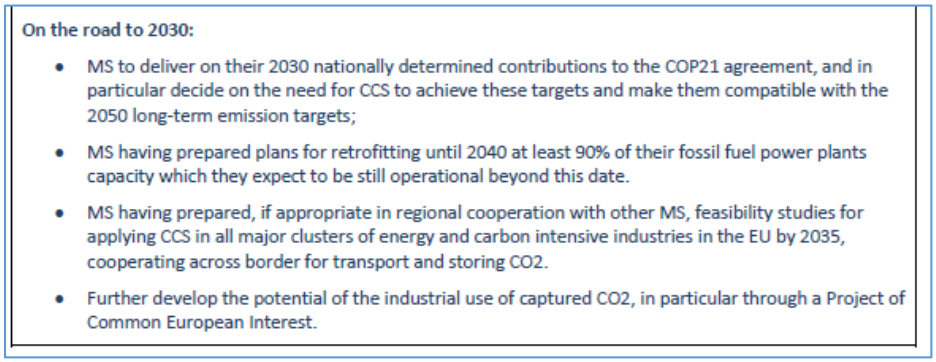
6.j. BioCCS and Biofuels: These are important implications of COP21.

6.k. Hydrogen: COM needs to unlock the H2 Joint Undertaking to become relevant for the whole energy system of Europe.

6.l. With reference to: "…Completed feasibility studies for the use of captured CO_2…" and to "…At least 4 pilots on promising new technologies for the production of value added chemicals from captured CO_2…" We consider these two actions are internally inconsistent as written - the result of the feasibility studies should be known before developing pilots.

6.m. The final bullet needs clarification.

7. Proposed key objectives and targets in CCS and CCU – By 2030 (p. 5)



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.

Comments to 'On the road to 2030'

7.a. With reference to: "…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…"; This is important but the timing is too late. We propose it should be linked to the MS reporting deadline to Energy Union in 2021.

7.b. With reference to "…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 will have to comment- note fossil fuel plants - ie both gas and coal. The text is not clear. Problem is national. Feasibility studies must be well before 2030. Should not be 90% related to capacity – but to electricity produced/energy delivered, due to new energy system with large RES portion and the resulting need for backup power.

7.c. With reference to "…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 CO_2…" This is too late and we will miss on the 2050 targets for sure. Project development has to start a long way in advance. Feasibility studies should be prepared by 2020 leaving 10 years for implementation.

7.d. With reference to "…Further develop the potential of the industrial use of captured CO_2, in particular through a Project of Common European Interest…" CO_2 use is not important in order to fight climate change. One option might be to develop a KPI that encourages permanent storage – i.e. we propose the following KPI:

- For any CCUS project, >90% of CO_2 captured must be permanently stored regardless of intermediate uses. Otherwise, the reactivation of CO_2 with (excess) regenerative power may still be useful as a feedstock for carbon containing fuels or chemicals in future carbon cycle scenarios. However, and important to note is that this is not directly comparable to CCS.

7.e. Focus should be on long-term scenarios rather than on the development of one particular project.

8. Some basic Key Performance Indicators (p. 6)

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 $€_{2013}$ (data based on the EC report "ETRI 2014 – Energy Technology Reference Indicator projections for 2010-2050").*

Comments:

8.a. Metrics do not allow measurement of progress on targets and should therefore include:
- i) No. of pilots
- ii) No. of feasibility studies
- iii) No. of commercial-scale projects (not demos)
- iv) Mt/year permanently stored
- v) MS actions that will lead to x number of CCS clusters.

8.b. All of the above should include intermediate targets for 2025, as well as 2020 and 2030

8.c. Too much focus on CCS from power.

8.d. Should have more on CO_2 transport, bioCCS, hydrogen from fossil with CCS and industrial emissions.

9. Some recommendations on financing CCS demonstration and deployment (p. 6)

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.

No further comment – all comments made above in response to specific questions.

10. Annex 1 Relevant actions of the 'Towards an Integrated Roadmap of the SET Plan

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' 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

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**

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

Comments:

10a. Advanced Research Programme:

CO2 Storage

We welcome the KPI on storage permits. But - this should be coupled to realistic plans to undertake site-specific storage appraisals to support the permit applications, as storage site development might take more than 5 years for each project. Effective co-operation between COM and the relevant SET-Plan countries are thus needed.

CO2 Capture

ACTION 1: R&D for supporting pilots and demonstration projects to operate in a renewable dominated energy system:

a. Fundamental research will be needed to solve issues that arise during piloting and demonstration.
b. Interaction of the capture system with other energy-sub-systems can change the performance of a capture system. E.g. the use of renewable energy for CO_2 stripping can lower the carbon footprint of a capture system.
c. A renewable dominated energy mix is likely to cause more fluctuations for the power plant and subsequently for the capture plant. The capture plant operations need to be adapted or new processes have to be developed as 'buffer' systems.

ACTION2: Proof of concept of low cost capture technologies for power and pan-industrial utilization

d. It is not clear whether pan-industrial also comprises power here.
e. Because of the high capture costs it remains a challenge to develop low cost capture for power.
f. Low cost is key, not efficiency. A highly efficient- but expensive process will not be used.
g. Basic research should focus on optimized solutions for 2nd optimized plants; 1st gen plants cannot wait for further fundamental research.
h. Innovative means for capture from small sources could be considered as a long-term target.
i. Focus should be on fundamental research for advanced options rather than on short term demonstration of non-competitive technologies.

Competitive CCS value chains:

Note that for CO_2 transport/value chains there is a difference between short term needs and long term needs:

a. Short term needs include initial commercial-scale operation which will provide fundamental data on aspects such as corrosion data and impact of minor impurities.
b. Long-term needs may require more focus on smaller scale distributed CCUS transport systems, linked to regional systems, depending on how much CO2 is produced by fossil (and biomass) power plants, and liquid transport on ships.

Conversion of CO_2 from Process Flue Gases:

a. Delete 'from Process Flue Gases". A separation step to concentrate CO_2 before converting CO_2 into something else is usually needed.
b. Action 2.: In the context of climate change mitigation, it should be noted that the carbon flow of those chemicals is negligible compared to the amount of CO_2 emitted globally.
c. Action 3: Delete or clarify: what kind of R&I work needs to be carried out to allow "access to competitive CO_2 for chemical conversion"?

10b. **<u>Industrial Research and Demonstration Programme</u>:**

Conversion of CO_2 from Process Flue Gases:

a. It seems premature to launch large scale demonstration projects for process routes that are currently at level TRL1-2 when referring to process options with relevant CO_2 avoidance potential.
b. Action 2: it is also difficult to understand the reason to prioritise this route in this document when, to our knowledge, no progress has been reported in the open scientific and technical literature on "ex-situ" mineral carbonation to overcome the fundamental difficulties to accelerate the reaction rates. Carbonation of industrial residues is a niche application from a climate change perspective.
c. 'R&I is needed to maximize storage potential in EOR and reduce costs, especially in offshore (North Sea) environments.