ZEP Advisory Council 50

22nd March 2017

Agenda Item 6: SET-Plan TWG9 CCUS

6.a. SET-Plan TWG9 CCUS Update

Appended to this paper is an update for the SET-Plan TWG9 CCUS.

6.b. SET-Plan TWG9 CCUS draft Implementation Plan

Appended to this paper is the SET-Plan TWG9 CCUS draft Implementation Plan.

6.c. Unspent NER300 funds discussion paper

Appended to this paper is the discussion paper regarding unspent NER300 funds.

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Agenda Item 6.a: SET-Plan TWG9 CCUS update

The Declaration of Intent (DoI) for CCUS, adopted by the SET-Plan Steering Group in September 2016, has identified ten specific targets for CCS and CCU by 2020. These include the operation of at least one full-chain CCS project by 2020, FEED for at least one full-chain industrial CCS project, targets on project development, and Member State analysis on the likely contribution of CCS to national energy systems. The Temporary Working Group (TWG) 9 on CCS/CCU is co-chaired by William Christensen (Norway), Joëlle Rekers (Netherlands) and Graeme Sweeney (ETIP ZEP), with participation from 10 Member States and around 30 stakeholders. Since its first meeting in November, the Secretariat has been working with the co-chairs and stakeholders to produce an Implementation Plan, identifying the technical and non-technical activities needed to deliver the 10 targets for CCUS set out in the DoI.

At the last meeting of the SET-Plan TWG9 CCUS, which took place on 15th February in The Hague, a draft version of the Implementation Plan was discussed (appended as pre-read 6.b). As part of this process, 7 'Research and Innovation Activities' have been identified, which may deliver one or more of the 10 SET-Plan targets:

- **R&I activity 1**: Delivery of the ROAD project (target 1)
- **R&I activity 2**: Delivery of regional CCUS clusters, including feasibility for a European hydrogen infrastructure (targets 2 & 3)
- **R&I activity 3**: Project of Common European Interest for CO_2 transport infrastructure (target 4)
- **R&I activity 4**: Progressing the European CO_2 Storage Atlas (target 5)
- **R&I activity 5**: CO_2 storage pilots in operation (target 7)
- **R&I activity 6**: CO_2 capture pilots (target 6)
- **R&I activity 7**: 3 Pilots on promising new technologies for use of CO_2 (target 8 & 9)
- **R&I activity 8**: CCUS modelling for policy development (target 10)

The Secretariat are currently assisting in the drafting of a second iteration of the Implementation Plan, following the TWG meeting in February, which will be reviewed at the next meeting of the TWG9 in April (date and venue to be confirmed in due course). A particular focus now is the identification of gaps in the Implementation Plan, where existing projects may be insufficient to meet the SET-Plan targets, and where further projects, implementation instruments, or funding (including proposals for the reuse of NER300 funds – please find the discussion paper appended as pre-read 6.c) may be required. The intention is that a final draft of the Implementation Plan will be submitted to the Commission by late April/early May, approximately six months since the

adoption of the DoI, followed by endorsement of the finalised Implementation Plan by the SET-plan Steering Committee.

SET-PLAN TWG9 CCUS Implementation Plan

The agreed specific targets addressed in this Implementation Plan have been defined in the Declaration of Intent under SET Plan Action 9:

Target 1: At least one commercial-scale, whole chain CCS project operating in the power sector

Target 2: At least one commercial scale CCS project linked to an industrial CO2 source, having completed a FEED study

Target 3: SET Plan countries having completed, if appropriate in regional cooperation with other MS, feasibility studies on applying CCS to a set of clusters of major industrial and other CO2 sources by 2025-2030, if applicable involving cooperation across borders for transporting and storing CO2 (at least 5 clusters in different regions of the EU)

Target 4: At least 1 active Project of Common European Interest for CO2 transport infrastructure, for example related to storage in the North Sea

Target 5: An up-to-date and detailed inventory of the most suitable and cost-effective geological storage capacity (based on agreed methodology), identified and accepted by various national authorities in Europe

Target 6: At least 3 pilots on promising new capture technologies, and at least one to test the potential of sustainable Bio-CCS at TRL 6-7 study

Target 7: At least 3 new CO2 storage pilots in preparation or operating in different settings

Target 8: At least 3 new pilots on promising new technologies for the production of fuels, value added chemicals and/or other products from captured CO2

Target 9: Setup of 1 Important Project of Common European Interest (IPCEI) for demonstration of different aspects of industrial CCU, possibly in the form of Industrial Symbiosis

Target 10: By 2020, Member States having delivered on their 2030 nationally determined contributions to the COP21 agreement, and having identified the needs to modernise their energy system including, if applicable, the need to apply CCS to fossil fuel power plants and/or energy and carbon intensive industries in order to make their energy systems compatible with the 2050 long-term emission targets

Ongoing R&I Activities

The SET-PLAN TWG9 have identified 8 R&I activities required to deliver each of the 10 agreed targets listed under the Declaration of Intent under action 9. Deliverables under each of the R&I activities comprise of ongoing projects, in addition to proposals for additional actions required to meet targets. R&I activities outlined in detail within this paper, and summarised below:

R&I activity 1: Delivery of the ROAD project (target 1)

R&I activity 2: Delivery of regional CCS clusters, including feasibility for a European hydrogen infrastructure (targets 2 & 3)

R&I activity 3: Project of Common European Interest for CO_2 transport infrastructure (target 4)

R&I activity 4: Establish a European CO_2 Storage Atlas (target 5)

R&I activity 5: CO_2 storage pilots in operation (target 7)

R&I activity 6: CO_2 capture pilots (target 6)

R&I activity 7: 3 Pilots on promising new technologies for use of CO_2 (target 8 & 9)

R&I activity 8: CCS modelling for policy development (target 10)

Proposed Flagship activities

A number of 'Flagship Activity' have been proposed, defined under the SET Plan Common Principles as a best example of how an R&I activity may deliver targets. 6 Flagship activities have been identified:

Flagship activity 1: The ROAD Projects (R&I action 1)

Flagship activity 2: Norwegian industrial CCS cluster (R&I action 2)

Flagship activity 3: Port of Rotterdam CO_2-Hub (R&I action 2)

Flagship activity 4: North East UK CCS clusters (R&I action 2)

Flagship activity 5: Project of Common European Interest for CO2 transport infrastructure (R&I action 3)

Flagship activity 6: European CO_2 storage pilot (R&I action 5)

R&I activity 1: Delivery of the ROAD project (target 1)

The Rotterdam capture and storage project – abbreviated ROAD – will be a full-chain CCS project at a coal-fired power plant at Maasvlakte. The Dutch government has made available a subsidy of €150 million to facilitate the project. The project also has a subsidy of €180 million from the European EEPR fund. The project plan has undergone changes since the project was first designed. Negotiations with partners, the European Commission and the Dutch government need to be concluded satisfactorily before the project will scale up again and prepare for FID. Delivery of the ROAD project will be aided by the Rotterdam CO_2 hub at the Port of Rotterdam. The Port of Rotterdam has an excellent position for the development of a Western Europe CO_2 Hub connecting the offshore storage fields with the Dutch heavy industry, Antwerp and Germany (and more).

Monitoring mechanism:

- Completion of ROAD FID by [date]
- Establishment of ERA-NET co-fund under Horizon 2020
- Full-chain CCS project in the power sector operational by 2020

Expected deliverables:

- Full-chain ROAD project operational by 2020. [ongoing]
- Removal of legislative and administrative barriers to the project through Dutch Government support. An example is current adaptations to the Mining Law to enable simultaneous production and permanent storage in the same reservoir. [ongoing]
- The Port of Rotterdam Authority will support the CC(U)S development on the following 5 area's: [planned]
    - Create an open backbone CO_2 pipeline in the Port of Rotterdam, in order to connect Offshore Storage fields, Users of CO_2 and Sources of CO_2;
    - Capturing CO_2 from the sources/companies and connect it to the CO_2 hub;
    - Connecting Offshore Storage fields with the Port (Connection area / interface between land/port and sea);
    - Re-use of CO_2 in order to attract strategic interesting companies/industries to strengthen the local clusters (e.g. EOR, building blocks for chemical processes, Green Houses);
    - Connection possibilities to other regions in order to support them in lowering their local CO_2 footprint.

Timeline:

- The ROAD project is expected to be operational in 2020
- ERA-NET Co-fund expected to be established in 2017

Party/ies:

- Ongoing support from the European Commission, Dutch Government, European Commision, GCCSI, Uniper and Engi, ROAD Maasvlakte C.V, Port of Rotterdam, Oranji Nassau Energi.

Implementation instruments:

- EEPR
- Horizon 2020

Indicative financing contribution:

- €180 million of EU support through the European Energy Programme for Recovery (EEPR)
- €150 million Dutch Government
- €15 million Port of Rotterdam
- €5 million GCCSI
- ERA-NET Co-fun CCS Demo up to €60 million, to date a €20 million contribution has been committed by the European Commission, with several countries committed to the ERA NET Co-Fund.

R&I activity 2: Delivery of regional CCS clusters, including feasibility for a European hydrogen infrastructure (targets 2, 3 & 10)

The ambition of the Norwegian Government is to build a full scale CCS demonstration by 2022. Feasibility studies have been concluded and conceptual studies will start early 2017. Three industrial partners have completed studies of CO2 capture; capture of flue gas at cement production site in Breivik (Norcem AS); three sources at the ammonia plant in Porsgrunn (Yara Norge AS); and a waste incinerator at Klemetsrud (Waste-to-Energy Agency in Oslo). Gassco has studied options for ship transport of CO2 and Statoil has studied three sites on the NCS for storage.

The planned Rotterdam CO_2 hub at the Port of Rotterdam will collect emissions from industrial sources and transfer and store these offshore. There will be significant synergies with ROAD. The hub could be the starting point of large scale CCS connecting all large CO2 point sources in the Rotterdam area. CO2 point sources further away could also benefit from the hub. CO2 could be transported for CO2 storage locations in the North Sea and could also be used for enhanced oil recovery (EOR)

The North East UK CCS clusters will link up existing industrial hubs with transport and storage infrastructure in the North Sea Basin. Industrial operators in the Tees Valley region of North East England have come together to design and propose a CCS cluster that allows multiple sources of CO_2 to use a common transport and storage infrastructure.

Meeting the requirements of Target 3 of the SET-PLAN (completed feasibility studies for 5 CCS clusters) will require the identification of regions which may host CCS clusters, requiring 2 additional feasibility studies. In order to achieve geographical balance proposals for projects located in Eastern Europe should be prioritised.

A European hydrogen infrastructure combining CCS and hydrogen produced from CCS could pave way for a cost effective and climate friendly solution. A first step will be a topix on Hydrogen in the Horizon 2020 energy work programme for 2020.

<u>Monitoring mechanism:</u>

- Completion of FEED studies for 5 CCS clusters

<u>Expected deliverables:</u>

- Delivery of FEED studies for Norwegian industrial CCS clusters [ongoing]
- Further feasibility and FEED studies for the Port of Rotterdam CO_2-Hub project and ROAD project [ongoing]
- Completed FEED studies for North East UK CCS cluster, including the Teesside industrial complex and further work in Grangemouth, Scotland.
- Support for feasibility studies required to identify 2-3 additional European regions in which CCS may be developed, selected to maintain geographical balance in support for CCS projects [required]

<u>Timeline:</u>

- Norway CCS cluster FEED phase expected to be complete by 2019, with the aim to be operational by 2022.
- The ROAD project is expected to be operational in 2020

<u>Party/ies:</u>

Support from European Commission, Norwegian Government, Dutch Government, UK Government, Scottish Government, Tees Valley Combined Authority, Teesside Collective, Summit Power, Gassnova SF, Norcem AS, Yara Norge AS, Waste-to-Energy Agency in Oslo municipality, Gassco, Statoil. [Further parties to be indetified]

Implementation instruments:

- Funding for further feasibility and FEED studies [Links with unspent NER300 funds]

Indicative financing contribution:

- Expected planning- and investment costs for a Norwegian industrial CCS cluster is expected to be 800-1 400 M EUR (dependent on i.e. how many sources CO_2 will be captured from)
- €2-3 million to be made available for 2-3 feasibility studies for future European CCS clusters
- [Further financing information required from other parties and SET Plan TWG9 members]

R&I activity 3: Project of Common European Interest (PCEI) for CO_2 transport infrastructure (target 4)

Together with major stakeholders, the Dutch Government is exploring the possibilities to join forces with the Flanders and potentially UK government to register as a PCI with a modular CO_2 transport infrastructure that connects the Rotterdam harbour and the Antwerp harbour to storage reservoirs in the Dutch and UK sections of the North Sea. There are still uncertainties related to the timing and proponents. A feasibility study would include a study of applying CCS in the Rotterdam industrial cluster. The North Sea Basin Task Force (NSBTF) has already taken a first step to define how the infrastructure could look like. The ongoing Horizon 2020 project Gateway is a first step. The PCI should build on recommendations established by the Gateway project.

Monitoring mechanism:

Expected deliverables:

- Delivery of the Gateway project, providing a comprehensive integrated PCEI project providing a model for establishing European CO_2 infrastructure [ongoing]
- Delivery of the ROAD and Rotterdam CO_2-hub projects [ongoing]
- Feasibility study of applying CCS in the Rotterdam industrial cluster [ongoing]
- Register the CO2 infrastructure as a PCI en ensure funding through the PCI mechanism

Timeline:

- Gateway project initiated in 2011 with funding to 2017

Party/ies:

Ongoing support from European Commission, Dutch Government, UK Government, NSBTF

Implementation instruments:

- H2020
- Connecting Europe Facility
- [CCS Development Fund / unspent NER300 funds]
- National Government programmes and funds

Indicative financing contribution:

- Gateway project awarded €787,000 funding under Horizon 2020
- EU and National funding for the Rotterdam Nucleus PCI project still to be confirmed.

R&I activity 4: Establish a European Storage Atlas

In order to enable first-mover projects CO_2 storage capacity must be made available, and large-scale potential storage reservoirs identified in the form of a European CO_2 storage atlas. Several versions of European storage atlases were generated, the most recent version of which is the CO2StoP Atlas. This atlas is to be released in 2017 via EC JRC. The atlas will be embedded in the EuroGeoSurveys' European Geological Data Infrastructure (EGDI). A number of European Countries have completed assessments and databases of storage resources with higher levels of information detail. The Norwegian Petroleum Directorate Storage Atlas was published in 2014, mapping the potential for CO_2 storage on the Norwegian Continental Shelf. The Strategic UK CO_2 Storage Appraisal Project was published in 2016, and is open access, licensed to The Crown Estate and British Geological Survey. These studies could be the starting point for establishing an updated European CO_2 storage atlas. This R&I activity will also benefit from action taken under R&I activity 5 (CO_2 storage pilots in operation) which, when completed, may be used to asses and validate storage assessments within the European Storage Atlas.

A European atlas of storage capacity facilitates project developers to find areas which are prospective for CO2 storage. The atlas will reflect different levels of maturity in defining storage capacity across the countries in Europe.

Further in-depth appraisal of the storage potential in specific regions and at specific sites will be necessary to deliver certified or bankable storage capacities. This part of the workfklow is best organized at the level of individual member states or regions with coordination at the European level. Outcomes of more detailed assessments are to be used to update the European storage atlas.

Monitoring mechanism:

- Agreement on a staged methodology for the determination of storage capacity at different levels of detail
- Agreement on and implementation of organisational structure
- Delivery of a storage atlas based on agreed uniform methodology for member states and regions with CCS policies and plans

Expected deliverables:

- Methodologies to evaluate storage potentials defined, including a risk and liability assessment; work on storage capacity determination ongoing in ENOS project (WP2)
  It is recommended to include dynamic CO_2 assessment (the majority of current assessment is static and do not take into account some useful aspects such as Darcy flow calculations, migration pathways and dissolution effects. These parameters can guide the appropriate monitoring techniques (expensive part of CO_2 storage) and the optimisation of a CO_2 storage project.It is also interesting to develop a cost model to improve the CO_2 storage assessments.

- Identification of an existing, or create a new, body to collect and coordinate storage information.
- Norwegian Petroleum Directorate Storage Atlas- database was published in 2014 and provides ongoing information for future exploration for CO_2 storage sites. [completed]
- Strategic UK CO_2 Storage Appraisal Project- database was published in 2016 and is publically available, providing an ongoing resource to inform decisions on the economics of storage opportunities. [completed]
- Speicherkataster Storage Catalogue of Germany- published open access in 2011 [completed]
- NSBTF- process will join up the existing storage assessments. [ongoing]
- Netherlands CO2 Transport and Storage Plan [ongoing]

- FENCO Utsira Aquifer (Germany) Analysis of potentials and costs of CO2 storage in the Utsira aquifer in the North Sea [completed]
- Collation of National storage assessments to produce a European Storage Atlas [required]
- Delivery of small scale storage pilots can be used to validate the storage assessments outlined above. [required under R&1 activity 5]

- Release of CO2StoP atlas in 2017
- Agreement on fit-for-purpose methodology for storage capacity determination 2019
- Release of completed and updated European storage atlas in 2020

Timeline:

- Norwegian Petroleum Directorate Storage Atlas- ran from 2011-2014
- Strategic UK CO_2 Storage Appraisal Project- published in 2016
- Speicherkataster Storage Catalogue of Germany- ran from 2008-2011
- Netherlands update to the 2010 CO_2 Transport and Storage Plan- will be undertaken from 2016-2018
- FENCO Utsira Aquifer (Germany) Analysis ran from 2009 - 2010

Party/ies:

Support from European Commission, Norwegian Government, Norcem AS, YaraNorge AS, Waste-to-Energy Agency in Oslo, Gassco, Statoil, UK Government, ETI, Pale Blue Dot, Dutch Government, UK Government, German Government, Universität Stuttgart; Copernicus Institute Utecht; University College London; Riso DTU, ENOS project Consortium, EuroGeoSurveys.

Implementation instruments:

- H2020 2018/19 funding call

Indicative financing contribution:

- £4 million spent on the Strategic UK CO_2 Storage Appraisal Project
- Netherlands CO2 Transport and Storage Plan will be funded by the Dutch Government
- Speicherkataster Storage Catalogue of Germany- €1.067 m state funding; €0.3 m private funding
- € 0.178 million State spent on FENCO Utsira Aquifer (Germany) Analysis

- 10s of million Euro needed for further appraisal in selected regions and completion of the atlas

R&I activity 5: CO_2 storage pilot in operation (targets 5 & 7)

Work has already been undertaken to produce comprehensive databases containing resources to inform future exploration of CO_2 storage sites, and economic decisions, with further action recommended under R&I activity 4 in the creation of a European Storage Atlas. The Dutch Government is updating its 2010 CO_2 transport and storage plan. The technical plan will focus on likely storage reservoirs and the likely development of transport infrastructure under various scenarios. This technical part of the plan will be finalised in 2017. The organisational part will follow thereafter. Initial pilot projects, planed under R&I activities 1-4, can be used to validate these storage assessments. Similar plans should be established in all MS and by aligning all national plans it will be possible to identify CO_2 storage pilots that could be established as joint European storage pilots.

In order to contribute to target 7, the storage pilots/deliverables that will be developed should comply with the standards listed below.

- Storage wells/sites bigger than 1000 ton and smaller than 100.000 ton
- All CO_2 storage pilots must ensure large outreach to the public. Visitor centre and open communication to allow
- At least one of the CO_2 storage pilots must be off-shore
- Providing information; output of the CO_2 storage pilots must support large-scale storage
- CO2 storage pilots should employ and verify new monitoring – and visualisation technologies (complex monitoring system for CO_2 storage is part of security and public acceptance issues)
- TRL 6-8

<u>Monitoring mechanism:</u>

[to be discussed]

<u>Deliverables:</u>

It is hoped that each of the following projects should be able to deliver at least 1 pilot:

- Hontomín TDP for CO2 geological storage in Spain, TRL 6-7 [ongoing]
- LBr1 Czech CO2 storage pilot project, current TRL 4, envisaged TRL 5 [ongoing]
- Pilot CO2 dissolved in France, small storage units suitable for small emitters, From TRL 5 To TRL 6/7 [ongoing]
- The ENOS project, developing, testing and demonstrating key technologies specifically adapted to onshore storage. TRL? [ongoing]
- ECCSEL NatLab Italy, TRL? [ongoing]
- Sotocarb, Italy [ongoing]
- Continuation of geochemical effects of the flooding in natural and experimental rock-(pore) water systems and numerical models (Hungary) [ongoing]

<u>Timeline:</u>

- Pilot CO2 dissolved in France will run from 2016-2017 (18 months)
- Hontomín TDP will run from 2016-2020
- Sotocarb 2015 – 2016
- ECCSEL 2015 – 2017
- LBr1 Czech CO2 storage pilot project 2015-2025

<u>Implementation instruments:</u>

- H2020
- Norway Grants 2014-2021

- Innovation Fund

Indicative financing contribution:

- Pilot CO2 dissolved in France €2-3 million funding (35% state funding, 65% funding from project partners).
- Sotocarb project € 340.630 private funding
- Hontomín TDP €3.2 M (80% from H2020, 20% from Spanish Government)
- ENOS project: €12.580.733,75 in total- 1.005.206,25 € for OGS (100% from EC)
- ECCSEL €3252280 in total- €223.295 for OGS (100% from EC)
- 2.8 M€ from Norway Grants (2015-16), 100 k€ from H2020 (ENOS project). Possible future funding: Norway Grants 2014-2021 / Horizon 2020 / Innovation Fund

Party/ies:

Hontomín TDP for CO2 geological storage in Spain: Fundación Ciudad de la Energía (CIUDEN), ECCSEL Pilot CO2 dissolved in France: Geogreen (France), CFG Services (France), Enertime (France), Partnering in Innovation (USA), BRGM (French geological Survey), GeoRessources (Université de Lorraine), IRENEE (Université de Lorraine), LEO (Université d'Orléans), REGARDS (Université de Reims), SET (Université de Pau et des Pays de l'Adour). ENOS project: BRGM, OGS, BGR, BGS, CGS, CIEMAT, CIUDEN, FLODIM, GGR, IDIL, IRIS, NHAZCA, PLC-3, SGIDS, SILIXA, SOTACARBO, TNO, UNIROMA1, UNOTT, CO2GeoNet. ECCSEL: NTNU, OGS, TNO, CIUDEN, CERTH, BRGM, PGI-NRI, GIG, BGS, SINTEF, SINTEF ER, SINTEF PR, ETH, SOTACARBO. LBr1 Czech CO2 storage pilot project: Czech Geological Survey, IRIS, UJV Rez, a.s., VSB - Technical University of Ostrava, Miligal, s.r.o., Masaryk University in Brno, Research Centre Rez

R&I activity 6: CO_2 capture pilots (target 6)

Building industrial scale CCS projects will generate many new challenges that can best be solved by R&D in parallel with large scale activities. An iterative process is needed where R&D projects address industrial challenges and results from the R&D projects are implemented in the large scale projects. Within CO_2 capture CO_2 pilots are needed to ensure fast and cost effective R&D activities.

Monitoring mechanism:

Objectives for capture pilots/deliverables:

- Energy efficiency: 30 % improvement compared to current state of the art
- The materials used in the capture technology are environmentally benign
- Capture rate above 90 % (i.e. capture rate as close to 100 % as possible, while at the same time ensuring energy efficiency in the capture process)
- Potential to scale up: Promising capture technologies are applicable for power plants and energy intensive industries in particular the iron, steel, cement and refinery sectors; industry expresses an interest to make investment in the technologies
- TRL 6-7
- Flexibility; improved approaches and processes for effective integration of CO2 capture is needed in power plants and relevant energy-intensive industry subject to large variability of load changes (SET-plan Energy Integrated Roadmap Annex 1 part 2, 2014, p. 122)
  Project proposals for testing the potential of sustainable Bio-CCS at TRL 6-7 must prove to be in line with the sustainable development policies of the EU

Expected deliverables:

- Continuation of Cryocap in France, currently at TRL 6 with TRL 9-10 envisaged at the end of the project [ongoing]
- Technology Centre Mongstad, TCM, [ongoing] is one of the most advance post combustion CO_2 capture pilots. Several vendors have already qualified their CO_2 capture technologies at TCM. Onwards to 2020 TCM could play a key role by providing test campaigns that are needed before CO_2 capture technologies can be deployed in full scale plants [ongoing]
- AVR Waste Incineration at Duiven in the Netherlands, TRL 5-6 [proposed]
- Continue stream reforming integrated with chemical looping combustion (P39621-1) [ongoing]

Implementation instruments:

- National research council
- Horizon 2020

Indicative financing contribution:

- €30 funding for Cryocap project (33% public funding, 67% private funding).
- Funding for AVR Waste Incineration at Duiven to be determined.

Timeline:

- Cryocap project in France will run from 2013-2018
- Technology Centre Mongstad will run from 2005-2019
- AVR Waste Incineration at Duiven will run from 2019

Party/ies:

Air Liquide, Gassnova SF, A/S Norske Shell, Sasol and Statoil ASA, AVR

R&I activity 7: CCU Action (target 8 & 9)

CO_2, as source of carbon, has the potential to be used in the manufacture of fuels and various chemicals. CO_2 utilisation (CCU) can therefore, in some cases, improve the economic value of CCS projects and the development of CCS technologies._CCU may delay carbon emissions to the atmosphere while reducing the consumption of the original feedstock and avoiding the other emissions associated to them. Processes such as enhanced oil recovery (EOR) result in permanent storage. In the other utilisation cases, CO2 is emitted later in the product chain, i.e. when the CO_2-product based is consumed.

The market-penetration of products from conversion of CO_2 is a process which needs time, and demonstrations of solutions with a net CO2 avoidance should therefore be initiated as soon as possible.

From Oct 2013 to Sept 2016, the European Commission funded a collaborative H2020 project called SCOT, for "Smart CO_2 Transformation". The project aimed at investigating the potential of using CO_2 as a resource for the strategic development of Europe. The conclusions are summarised in three deliverables: a Vision document[1] which explains how CO2 Utilisation could enable European industry to be more resource-efficient, sustainable and competitive; a Strategic Research Agenda which highlights technological and non-technological hurdles which must be overcome; and a Joint Action Plan[2] which identifies concrete measures which should be implemented, including the creation of a cross-sectorial European Association dedicated to CO_2 Utilisation.

Building on the important momentum created by the SCOT project, a Founding Consortium of 26 organisations[3] assembled in Oct-Dec 2016 with the objective to jointly prepare the creation by the middle of 2017 of such a European Association dedicated to CO_2 Utilisation. The Consortium is coordinated by Greenwin, the Competitiveness Cluster of the Walloon region (Belgium), who already lead the SCOT project.

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[1] http://www.scotproject.org/content/vision-smart-co2-transformation-europe

[2] http://www.scotproject.org/content/seria-and-jap

[3] As of 1 January 2017, the consortium is composed of the following 26 partners:

- **13 multinational industry leaders** covering all key relevant sectors from the CO_2 Utilisation value chain:
  - Cement: Cemex, Heildelberg Cement and Lafarge-Holcim
  - Chemicals: Total
  - Equipment manufacturing: CMI Group
  - Industrial gases: Air Liquide and Praxair
  - Lime: Carmeuse and Lhoist
  - Power: Engie
  - Steel: ArcelorMittal and ThyssenKrupp
  - Waste Management: Suez
- **4 specialized SMEs** developing CO2-utilisation technologies: Atmostat (France), Carbon 8 Systems (UK), Carbon Recycling International (Iceland) and Sunfire (Germany)
- **5 research organisations**:
  - ECN (Netherlands)
  - IFP-EN (France)
  - ICIQ (Spain)
  - SINTEF (Norway)
  - VITO (Belgium)
- **1 university**: the University of Sheffield (UK)
- **3 clusters**:
  - Axelera (France)
  - Dechema (Garmany)
  - GreenWin (Belgium)

From February to May 2017, the 26 Founding Partners will jointly work on the definition of a preliminary strategic roadmap for the large scale deployment of CO_2 Utilisation in Europe for 3 major fields of application[4]:

- Transforming CO2 into gaseous and liquid synthetic fuels (such as methane, methanol or olefins), thereby offering energy storage solutions for energy systems with a significant portion of intermittent renewable electricity generation, as well as low-carbon solutions for the transportation sector;
- Using CO2 for the production of organic chemicals (e.g. polymers and non-fuel chemicals such as organic carbonates); as an alternative feedstock to fossil resources (oil and gas);
- Storing CO2 for long periods of time into useful building materials, e.g. by using CO2 to transform solid waste into aggregates or to accelerate the curing of fresh concrete in pre-cast construction elements.

The preparation of the roadmap will take place in 2 phases:

Phase 1. Develop a shared understanding of the state-of-the-art (Feb-March 2017)
The Founding Partners will conduct a transversal high-level analysis of the results of the key studies[5] published over the last few years about the technical, economic and environmental performance of different CO2-transformation technologies in the three fields of application above. The objective is to develop a common view of where we stand today in terms of technico-economic feasibility and of potential environmental benefits, and to identify the key progress drivers, barriers and needs for public support if we want to bring CO2 transformation to the market at a large scale.

Phase 2. Identify topics for priority common projects (April-May 2017)
Based on the results of Phase 1, the Consortium partners will jointly define the generic projects which would be most relevant at three levels:

- Type A: large scale demonstration projects on complete value chains (TRL 9), to demonstrate industrial and commercial feasibility and determine the most relevant approaches to provide public support (where required);
- Type B: pilot projects (TRL 6-8) to validate technology and business models at semi-industrial scales; and
- Type C: R&D projects at TRL 4-5 only for breakthrough technologies which have the potential to open radically new commercial opportunities for CO2 conversion, via new chemistries and/or new processes.

For types A and B, only projects gathering a strong interest (and willingness to invest) from a critical mass of industrial partners will be selected.

Expected deliverables:

It is proposed that the priority common projects identified by the CCU community (represented by the Consortium partners) at the end of Phase 2 above (in particular projects of type A and B) be considered by TWG9 as the basis for defining the content of the Implementation Plan for Target 8 ("at least 3 new[6] CCU pilots") and Target 9 ("1 Important Project of Common European Interest for

[4] These topics are discussed in the SET Plan "Towards an Integrated Roadmap" document, under Heading 3, Challenge 3 "Alternative Fuels" (pp 116-121) and Heading 4, Challenge 4 "Conversion of CO2 from Process Flue Gases" (pp 133-137).
[5] Independent studies commissioned by governmental agencies from various Member States (BE, DE, FR, UK), by the Joint Research Centre of the European Commission, by the Global CO2 Initiative, by industry organisations such as CEFIC.
[6] These new projects will be in addition to the numerous CCU projects which are already ongoing (besides the projects listed by the contributing Member States in the TWG9 Excel table, more than 200 existing projects are identified in the database of the SCOT project http://database.scotproject.org/projects)

demonstration of industrial CCU). Member States will be largely consulted for the selection and location of such projects.

Party/ies:

Interested industrial partners from the Founding Consortium (+ additional ones if relevant), support from interested Member States and the European Commission.

Indicative financing contribution:

To be determined for each selected project: Private funding from interested industrial partners, complemented by funding from interested Member States and the European Commission.

Timeline:

The new projects will be selected to be ready for starting implementation immediately

From February to May 2017, the 26 Founding Partners will jointly work on the definition of a preliminary strategic roadmap for the large scale deployment of CO_2 Utilisation in Europe for 3 major fields of application[7]:

- Transforming CO2 into gaseous and liquid synthetic fuels (such as methane, methanol or olefins), thereby offering energy storage solutions for energy systems with a significant portion of intermittent renewable electricity generation, as well as low-carbon solutions for the transportation sector;
- Using CO2 for the production of organic chemicals (e.g. polymers and non-fuel chemicals such as organic carbonates); as an alternative feedstock to fossil resources (oil and gas);
- Storing CO2 for long periods of time into useful building materials, e.g. by using CO2 to transform solid waste into aggregates or to accelerate the curing of fresh concrete in pre-cast construction elements.

The preparation of the roadmap will take place in 2 phases:

Phase 1. Develop a shared understanding of the state-of-the-art (Feb-March 2017)
The Founding Partners will conduct a transversal high-level analysis of the results of the key studies[8] published over the last few years about the technical, economic and environmental performance of different CO2-transformation technologies in the three fields of application above. The objective is to develop a common view of where we stand today in terms of technico-economic feasibility and of potential environmental benefits, and to identify the key progress drivers, barriers and needs for public support if we want to bring CO2 transformation to the market at a large scale.

Phase 2. Identify topics for priority common projects (April-May 2017)
Based on the results of Phase 1, the Consortium partners will jointly define the generic projects which would be most relevant at three levels:

- Type A: large scale demonstration projects on complete value chains (TRL 9), to demonstrate industrial and commercial feasibility and determine the most relevant approaches to provide public support (where required);
- Type B: pilot projects (TRL 6-8) to validate technology and business models at semi-inustrial scales; and

[7] These topics are discussed in the SET Plan "Towards an Integrated Roadmap" document, under Heading 3, Challenge 3 “Alternative Fuels” (pp 116-121) and Heading 4, Challenge 4 “Conversion of CO2 from Process Flue Gases” (pp 133-137).
[8] Independent studies commissioned by governmental agencies from various Member States (BE, DE, FR, UK), by the Joint Research Centre of the European Commission, by the Global CO2 Initiative, by industry organisations such as CEFIC.

- Type C: R&D projects at TRL 4-5 only for breakthrough technologies which have the potential to open radically new commercial opportunities for CO2 conversion, via new chemistries and/or new processes.

For types A and B, only projects gathering a strong interest (and willingness to invest) from a critical mass of industrial partners will be selected.

Expected deliverables:

It is proposed that the priority common projects identified by the CCU community (represented by the Consortium partners) at the end of Phase 2 above (in particular projects of type A and B) be considered by TWG9 as the basis for defining the content of the Implementation Plan for Target 8 ("at least 3 new[9] CCU pilots") and Target 9 ("1 Important Project of Common European Interest for demonstration of industrial CCU). Member States will be largely consulted for the selection and location of such projects.

Party/ies:

Interested industrial partners from the Founding Consortium (+ additional ones if relevant), support from interested Member States and the European Commission.

Indicative financing contribution:

To be determined for each selected project: Private funding from interested industrial partners, complemented by funding from interested Member States and the European Commission.

Timeline:

The new projects will be selected to be ready for starting implementation immediately

[9] These new projects will be in addition to the numerous CCU projects which are already ongoing (besides the projects listed by the contributing Member States in the TWG9 Excel table, more than 200 existing projects are identified in the database of the SCOT project http://database.scotproject.org/projects)

R&I activity 8: CCS modelling for policy development (target 10)

Successful deployment of CCS requires technology development in parallel with policy development. Actions on technology improvement will reduce the cost related to CCS, but incentive mechanism are widely-acknowledged as necessary for early deployment of CCS projects in Europe. Beyond that, CCS is expected to be deployed when the cost of emitting CO_2 becomes higher than the cost of CCS. Policies and incentives putting a high enough cost on CO_2 emissions need to be implemented.

Establishing appropriate policy mechanisms at an EU and national level first requires an understanding of the potential role of CCS to energy systems decarbonisation through advanced energy systems and economic modelling. This in turn will require both improved understanding and access to an energy systems model able to analyse decarbonisation pathways stretching over several decades.

One example for such a tool is the JRC-EU-TIMES model, which is operated and maintained in-house at the Joint Research Centre for assessing long term development pathways for SET-Plan technologies.

The TIMES modelling framework is an established modelling paradigm developed within the ETSAP Implementation Agreement of the IEA[10] since more than 30 years and which now enjoys a broad global user base. A key element of the JRC-EU-TIMES model structure is its capability to capture the interaction between subsectors, e.g. between the transportation and power sectors. This enables the model to help in understanding cross-sectors synergies (e.g. modelling the shared cost-benefits between CCS deployment in industrial, power, heat and transport sectors) or side effects, making the JRC-EU-TIMES model suitable to identify for example the opportunity cost for CCS, the incremental change in the system costs caused by CCS exclusion. Furthermore, the comprehensive integration of hydrogen as a low carbon energy vector and its production alongside CCS and CCUS (e.g. synthetic fuels) have been implemented in the JRC-EU-TIMES model and could be easily updated to address specific scenarios / assumptions..

Methodological improvements of systemic modelling (in particular the interaction of the energy system with related fields) and concrete results for the role of CCS can be expected to materialise from recently started H2020 projects on modelling transitions pathways such as REEEM[11], SET-NAV[12], REFLEX[13] and MEDEAS[14].

The pan European analysis could be complemented by regional or MS specific case studies. Actions under this activity could include, for example, work being conducted in Sweden to build a broad assessment of socio-political prospects for deploying BECCS at the scales suggested in modelling scenarios through: 1) mapping prioritisations of BECCS among key actors and in national climate targets and strategies; 2) exploring factors that may influence preferences; and, 3) assessing how models can approximate BECCS' socio-political dimension. The project provides crucial input to more realistic mitigation scenarios and to the dis-/incentives for deployment of BECCS.

<u>Monitoring mechanism:</u>

<u>Expected deliverables:</u>

- Ongoing cooperation with the Dutch government to develop a CCS Roadmap in collaboration with industry in the Netherlands (oil and gas, power sector, industry) [ongoing]

[10] http://iea-etsap.org/
[11] http://www.reeem.org/
[12] http://www.set-nav.eu/
[13] http://reflex-project.eu/
[14] http://medeas.eu

- Premises for bioenergy with carbon capture and storage in the global response to climate change (P42390-1) [Sweden] [status?]
- Zero Emissions Platform Market Economics 5 Report

Implementation instruments:

- Horizon 2020
- National research councils
- [Collaborations between national energy ministries?]

Indicative financing contribution:

[for discussion]

Timeline:

[for discussion]

Party/ies:

[for discussion]

Identification of gaps

Activity	Relevant DoI Target(s)	Potential Gaps	Potential solutions
R&I activity 1: Delivery of the ROAD project	1	• No back-up projects in the event that the ROAD project does not reach FID • Capex funding • Potential operational funding gaps for any full chain power CCS project in the absence of agreed policy support from national governments	• Further (grant/equity) funding support made available by national governments and the Commission, e.g. through Horizon 2020 and unspent NER300 funds. • Potential role for the EIB in providing grants and enabling access to low-cost private finance
R&I activity 2: Delivery of regional CCS clusters, including a European hydrogen infrastructure	2, 3	• Not enough regional clusters identified • Access to characterised stores that have completed FEED • Funding for regional cluster feasibility and FEED studies	• New European funding calls published under Horizon 2020 (potentially leveraging unspent NER300 funds through a new CCS ERA-NET)
R&I activity 3: Project of Common European Interest for CO_2 transport infrastructure	4	• Delivery of a CO_2 PCI by 2020 requires established regulatory framework for applying and a submission being made in H1 2017. This is being progressed by DG Energy but any delays could result in target being undeliverable. • Funding for CO_2 PCI in the absence of early national CCS projects	• Funding support for development (feasibility/FEED) for CO_2 PCIs to support with application process (potentially leveraging unspent NER300 funds) • Funding support made available through CEF for any successful PCI proposals
R&I activity 4: Establish a European CO_2 Storage Atlas	5	• Lack of storage appraisal activity in particular regions of Europe • Funding for early storage appraisal in the absence of clear market signals that CCS will be required within a region	• Further R&D funding available under H2020
R&I activity 5: CO_2 storage pilots in operation	7	No gaps currently identified	
R&I activity 6: CO_2 capture pilots	6	No gaps currently identified	

Activity	Relevant DoI Target(s)	Potential Gaps	Potential solutions
R&I activity 7: 3 Pilots on promising new technologies for use of CO_2	8 & 9	• Bridging the gap between lab-scale pilots and pre-commercial pilots (i.e. larger scale demonstrations), including access to funding.	
R&I activity 8: CCS modelling for policy development	10	• Lack of projects identified in the spreadsheet • Lack of clear focus for how barriers can be addressed	• Further engagement with CCUS and academic/modelling communities • Establish a multinational CCS/hydrogen/energy systems modelling working group to determine necessary actions and deliverables • Funding through Horizon 2020

January 2017

Effective use of unspent NER300 funds for CCS projects

Discussion Paper for the SET Plan TWG9 CCUS and Climate Change Committee

EU leaders established the NER300 scheme to incentivise Member State and private sector investments in up to 12 CCS demonstration plants by 2015[1]. Despite initial ambitions, progress on CCS in Europe has been slow over the past decade and Europe now lags behind the North America and the Middle East in demonstrating and deploying the technology at a commercial scale.

For various reasons, including changes in the global economic and policy climate since 2010, the NER300 scheme has not been as successful for either CCS or renewables as the Commission and other stakeholders had initially hoped for. To date, only three projects awarded NER300 funding are operational and it is expected that up to €553 million of funding from the first NER300 call alone could become available by early 2017.

Under the Strategic Energy Technologies Plan (SET-Plan), SET-Plan countries have recently agreed and adopted 10 specific targets for CCUS, to be achieved by 2020[2]. With the availability of unspent NER300 funds, there is now an opportunity to reconsider the specific commercial challenges facing CCS and establish a dedicated CCUS Development Fund under Horizon 2020. This new Fund should be capable of delivering tangible progress against the SET Plan specific targets and help to unlock commercial deployment of CCUS in Europe – one of original aims of the NER300 programme.

Reusing unspent NER300 funds

Through the Climate Change Committee, Member States are currently considering four options for the unspent NER300 funds from the first NER300 call:

1. Topping up the future Innovation Fund as proposed in the ETS revision proposal
2. Allocation to existing financial instruments, e.g. European Fund for Strategic Investment (EFSI), InnovFin Energy Demo Projects (InnovFin EDP) or Connecting Europe Facility (CEF)
3. Increased support to projects awarded NER 300 funds.
4. Launch a third NER 300 call for proposals

Industry and other CCS stakeholders, including the European Zero Emission Technology and Innovation Platform (ZEP), have recommended that a dedicated CCS Development Fund is established under an alternative legislative framework to the NER300 scheme[3].

In the view of ZEP, which is the advisory body to the European Commission on CCUS technology and policy, options 3 and 4 would not address the underlying barriers to CCS deployment as the NER300 Decision would remain the legal basis for awarding and disbursing funds, whilst option 1, given the long lead times for some CCS projects, would not deliver sufficient funding on the scale and timeline necessary to achieve the SET-Plan targets for CCUS.

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[1] Commission Decision of laying down criteria and measures for the financing of commercial demonstration projects that aim at the environmentally safe capture and geological storage of CO2 as well as demonstration projects of innovative renewable energy technologies under the scheme for greenhouse gas emission allowance training within the Community established by Directive 2003/87/EC of the European Parliament and of the Council

[2] See Annex1

[3] http://www.zeroemissionsplatform.eu/index.php?option=com_downloads&id=1625

Option 2 proposes that funds are transferred to another existing financial instrument, and suggests EFSI, InnovFin and the CEF as potential locations for the funds. However, if an objective of the reallocation of unspent funds is to deliver progress on CCS in line with the original NER300 Decision, then the Climate Change Committee may also consider reallocating the funds to the Horizon 2020 programme.

EFSI and InnovFin are primarily loan-based financial instruments designed to support small and medium sized enterprises in delivering low carbon energy projects. Whilst EFSI potentially offers opportunities for CCS in the medium term, project developers have identified the importance of grant funding to supporting commercial scale CCS demonstration projects, which would not obviously be available under EFSI. The Connecting Europe Facility offers potential opportunities to support CO_2 transport Projects of Common Interest but the regulations mean it cannot be used to address the commercial barriers to CO_2 storage, capture or utilisation projects.

In the 2016/17 H2020 Work Programme, calls were included for CCS projects ranging from CO_2 storage pilots and R&D for capture technologies right through to a CCS ERA-NET for providing operational support to the ROAD project in the Netherlands. This level of flexibility could be integral to ensuring that EU funding is able to support projects covering the full range of CCUS targets agreed in the relevant SET Plan Declaration of Intent.

Considering the alternative options, Horizon 2020 appears to offer the best opportunity to support a range of CCUS projects and should be considered as a mechanism for disbursing a new CCS Development Fund. Whilst Horizon 2020 offers the most flexibility, however, such a proposal would require transferring unspent NER300 funds (governed by Member States) to the Horizon 2020 pot (which comes from the Commission's own budget), and therefore such a proposal is likely to require significant Member State ownership and buy-in.

Proposal for reallocating unspent NER300 funds

1. The Climate Change Committee should recommend setting aside a proportion of both the first and second traches of unspent NER300 funds to support delivery of the SET Plan Declaration of Intent specific targets for CCUS[4] through the Horizon 2020 framework. This would represent a dedicated CCS Development Fund that would enable the original purpose of the NER300 programme to be delivered, support delivery of SET Plan CCS targets and act as a source of bridging funds ahead of the implementation of the Innovation fund.

2. To ensure timely and flexible disbursement of the funds, the Climate Change Committee should vote in favour of CCS specific calls being established within the 2018/19 Horizon 2020 Work Programme, reflecting the 10 specific SET Plan targets for CCUS and the transfer of the ring fenced NER300 funds to the H2020 programme.

[4] The specific targets can be found appended.

Annex 1: Specific Targets for CCUS agreed under the SET-Plan

By 2020:

- At least one commercial-scale , whole chain CCS project operating in the power sector;

- At least one commercial-scale CCS project linked to an industrial CO_2 source, having completed a FEED study;

- SET Plan countries having completed, if appropriate in regional cooperation with other MS, feasibility studies on applying CCS to a set of clusters of major industrial and other CO_2 sources by 2025-2030, if applicable involving cooperation across borders for transporting and storing CO_2 (at least 5 clusters in different regions of the EU);

- At least 1 active Project of Common European Interest for CO_2 transport infrastructure, for example related to storage in the North Sea;

- An up-to-date and detailed inventory of the most suitable and cost-effective geological storage capacity (based on an agreed methodology), identified and accepted by various national authorities in Europe;

- At least 3 pilots on promising new capture technologies, and at least one to test the potential of sustainable Bio-CCS at TRL 6-7;

- At least 3 new CO_2 storage pilots in preparation or operating in different settings;

- At least 3 new pilots on promising new technologies for the production of fuels, value added chemicals and/or other products from captured CO_2;

- Setup of 1 Important Project of Common European Interest (IPCEI) for demonstration of different aspects of industrial CCU, possibly in the form of Industrial Symbiosis;

- By 2020, Member States having delivered on their 2030 nationally determined contributions to the COP21 agreement, and having identified the needs to modernise their energy system including, if applicable, the need to apply CCS to fossil fuel power plants and/or energy and carbon intensive industries in order to make their energy system compatible with the 2050 long- term emission targets.