**SET-PLAN TWG9 CCS and CCU**

**Implementation Plan**

# Introduction

The SET-Plan TWG9 CCS and CCU Implementation Plan outlines 8 key Research and Innovation (R&I) Activities, required to acheive the ambitious targets for CCS and CCU for 2020 agreed by the European Commission, SET-Plan countries, and industry, outlined in the 2016 Declaration of Intent.[[1]](#footnote-1) The Implementation Plan also indentifies the ongoing actions which will be required to meet the Key Performance Indicators which have been set for for 2030. The membership of the TWG9 comprises of 11 SET-Plan countries (the Czech Republic, France, Germany, Hungary, Italy, Norway, the Netherlands, Turkey, Spain, Sweden and the UK), industrial stakeholders, and research institutions.

## Key learnings from the Implementation Plan

The TWG9 Implementation Plan sets out the actions required to achieve the 10 targets for CCS and CCU, as introduced above. It identifies ongoing projects under each R&I Activity and proposes new actions to address gaps where the existing projects are seen to be insufficient to achieve these targets within the 2020 timeframe. This includes gaps in the funding instruments currently available from both Member States and the European Commission, required to progress a number of ongoing and proposed CCS and CCU projects.

In the past both EU and state funding instruments have had limited success in delivering progress on CCS projects in Europe. A key example is the estimated €2.1 billion of funding made available through the 2 NER300 calls in 2012 and 2014, of which only an estimated €65.7 million has been allocated. Currently proposals for re-allocating the remaining funds centre on 2 existing financial instruments: the InnovFin Energy Demo Projects (InnovFin EDP), and the Connecting Europe Facility (CEF), with the latter anticipated to be an important source of funding for projects awarded PCI status in 2017. The completion of a comprehensive Implementation Plan for CCS and CCU now presents a timely opportunity to assess how existing sources of funding, such as the NER300 and Innovation Fund may be best used to support projects in Europe. There are also opportunities to support projects through Horizon 2020 funding, which in the past has been an important enabler of CCS and CCU in Europe. Current proposals under the 2018/19 Energy Work Programme now show good alignment with the ongoing and proposed activities indentified within the Implementation Plan.

A further issue raised by the TWG9, and outlnied within the Implementation Plan, is the current status of the London Protocol. This prohibits the export of CO2 from a contracting party to other countries for injection into sub‐seabed geological formations. The protocol was amended in 2009 to enable cross‐border CCS projects, but the amendment must be ratified by two‐thirds of contracting parties to enter into force. Given the required number of ratifications and difficulties associated with the ratification process, it appears unlikely that two‐thirds of contracting parties will be in a position to ratify the amendment in the near term. Raising awareness among relevant government ministries of the importance to global CCS deployment of ratifying the London Protocol amendment should be a priority. Consideration should be given to options identified by the International Energy Agency[[2]](#footnote-2) that may be available to contracting parties under international law to address this barrier to CCS deployment pending formal entry into force of the 2009 amendment.

## Proposal to establish an ongoing ’Working Group 9 CCS and CCU’

In order to build on the lessons learned by the TWG9 during the process it is proposed that an ongoing ‘Working Group 9: CCS and CCU’ be established. It is envisaged that the aims of the Working Group 9: CCS and CCU will be twofold:

1. Maintaining an ongoing dialogue between the European Commission and the SET-Plan countries and stakeholders involved in the TWG9 to ensure that barriers to the progression of the CCS and CCU activities identified in the Implementation Plan can be continually identified and addressed.
2. Monitoring the progress of the actions outlined under the Implementation Plan, including the ‘monitoring mechanisms’ towards 2020.

It is proposed that following general agreement of the concept for the establishment of an ongoing ‘Working Group 9: CCS and CCU’ interested parties work alongside the SET-Plan Steering Committee and the European Commission to determine a suitable terms-of-reference, organisational structure, membership, and remit for the group.

## Guide to the Implementation Plan structure and terms

The structure of the Implementation Plan is based on the guidance of the European Commission’s Common Guiding Principles document, outlined by the SET-Plan Steering Committee. Whilst a number of the projects listed are expected to be operational within the 2020 timeframe, the long timescales involved in developing CCS projects mean that the progress of the activities identified may range from the completion of feasibility studies, up to the final investment decision by this date. To ensure that the momentum of projects, as well as the supporting policy actions, is not lost, proposals are included for actions needed beyond 2020, based on the ‘2030 Key Performance Indicators’ set out in the Declaration of Intent.[[3]](#footnote-3)

Below are definitions for key terms included under each R&I Activity within the Implementation Plan, which are based on the European Commission’s Common Guiding Principles.

|  |
| --- |
| **Definitions of key terms** |
| Monitoring mechanism | Key milestones for each project/action included under the R&I Activity, which will contribute to delivering the relevant SET-Plan target.  |
| Deliverable | Project or action which will deliver the relevant SET-Plan target.  |
| Other definitions which should be included here? |  |

Contents

[Introduction 1](#_Toc483310890)

[Key learnings from the Implementation Plan 1](#_Toc483310891)

[Proposal to establish an ongoing ’Working Group 9 CCS and CCU’ 2](#_Toc483310892)

[Guide to the Implementation Plan structure and terms 2](#_Toc483310893)

[Targets for CCS and CCU under the SET-Plan Action 9 6](#_Toc483310894)

[Research & Innovation Activities 7](#_Toc483310895)

[Flagship activities 7](#_Toc483310896)

[R&I Activity 1: Delivery of the ROAD project 9](#_Toc483310897)

[Overview of existing and planned activities 9](#_Toc483310898)

[Identified gaps 9](#_Toc483310899)

[Pathway to 2030 and beyond 9](#_Toc483310900)

[Table 1a: DOI Targets and Monitoring Mechanisms 10](#_Toc483310901)

[Expected deliverables and timeline 10](#_Toc483310902)

[Table 1b: Financing of planned activities to 2020 11](#_Toc483310903)

[Table 1c: Financing of planned activities to 2030 11](#_Toc483310904)

[R&I Activity 2: Delivery of regional CCS and CCU clusters, including feasibility for a European hydrogen infrastructure 13](#_Toc483310905)

[Overview of existing and planned activities 13](#_Toc483310906)

[Identification of gaps 14](#_Toc483310907)

[Pathway to 2030 and beyond 15](#_Toc483310908)

[Table 2a: DOI Targets and Monitoring Mechanisms 15](#_Toc483310909)

[Expected deliverables and timeline 16](#_Toc483310910)

[Table 2b: Financing of planned activities to 2020 17](#_Toc483310911)

[Table 2c: Financing of planned activities to 2030 18](#_Toc483310912)

[R&I Activity 3: EU Projects of Common Interest (PCI) for CO2 transport infrastructure 20](#_Toc483310913)

[Overview of existing and planned activities 20](#_Toc483310914)

[Identification of gaps 21](#_Toc483310915)

[Pathway to 2030 and beyond 21](#_Toc483310916)

[Table 3a: DOI Targets and Monitoring Mechanisms 21](#_Toc483310917)

[Expected deliverables and timeline 22](#_Toc483310918)

[Table 3b: Financing of planned activities to 2020 (this will be updated once the 2017 PCI list is finalised) 22](#_Toc483310919)

[Table 3c: Financing of planned activities to 2030 23](#_Toc483310920)

[R&I Activity 4: Establish a European Storage Atlas 24](#_Toc483310921)

[Overview of existing and planned activities 24](#_Toc483310922)

[Identified gaps 24](#_Toc483310923)

[Pathway to 2030 and beyond 24](#_Toc483310924)

[Table 4a: DOI Targets and Monitoring Mechanisms 25](#_Toc483310925)

[Expected deliverables and timeline 25](#_Toc483310926)

[Table 4b: Financing of planned activities to 2020 26](#_Toc483310927)

[Table 4c: Financing of planned activities to 2030 27](#_Toc483310928)

[R&I Activity 5: Advancing European Storage Capacity 28](#_Toc483310929)

[Overview of existing and planned activities 28](#_Toc483310930)

[Identified gaps 28](#_Toc483310931)

[Pathway to 2030 and beyond 28](#_Toc483310932)

[Table 5a: DOI Targets and Monitoring Mechanisms 29](#_Toc483310933)

[Deliverables and timeline 29](#_Toc483310934)

[Table 5b: Financing of planned activities to 2020 29](#_Toc483310935)

[Table 5c: Financing of planned activities to 2030 30](#_Toc483310936)

[R&I Activity 6: Developing next-generation CO2 capture technologies 31](#_Toc483310937)

[Overview of existing and planned activities 31](#_Toc483310938)

[Identified gaps 32](#_Toc483310939)

[Pathway to 2030 and beyond 32](#_Toc483310940)

[Table 6a: DOI Targets and Monitoring Mechanisms 32](#_Toc483310941)

[Expected deliverables and timeline 32](#_Toc483310942)

[Table 6b: Financing of planned activities to 2020 33](#_Toc483310943)

[Table 6c: Financing of planned activities to 2030 and beyond 33](#_Toc483310944)

[R&I Activity 7: CCU Action - Awaiting further input from CCU WG 35](#_Toc483310945)

[Overview of existing and planned activities 35](#_Toc483310946)

[Identification of gaps 36](#_Toc483310947)

[Pathway to 2030 37](#_Toc483310948)

[Table 7a: DOI Targets and Monitoring Mechanisms 37](#_Toc483310949)

[Expected deliverables and timeline to 2020 38](#_Toc483310950)

[Table 7b: Financing of planned activities to 2020 39](#_Toc483310951)

[Table 7c: Financing of planned activities to 2030 39](#_Toc483310952)

[R&I Activity 8: Understanding and communicating the role of CCS in meeting European and national energy and climate change goals 41](#_Toc483310953)

[Overview of existing and planned activities 41](#_Toc483310954)

[Identified gaps 42](#_Toc483310955)

[Pathway to 2030 42](#_Toc483310956)

[Table 8a: DOI Targets and Monitoring Mechanisms 42](#_Toc483310957)

[Expected deliverables and timeline 43](#_Toc483310958)

[Table 8b: Financing of planned activities to 2020 43](#_Toc483310959)

[Table 8c: Financing of planned activities to 2030 44](#_Toc483310960)

[Annex (attached as spreadsheet) 45](#_Toc483310961)

# Targets for CCS and CCU under the SET-Plan Action 9

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 EU Project of Common Interest (PCI) 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 as part of the Energy Union Governance their integrated national energy and climate plans for after 2020, 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

# Research & Innovation Activities

The SET-PLAN TWG9 has identified 8 Research and Innovation ‘R&I’ Activities required to deliver the 10 agreed targets listed under the Declaration of Intent on strategic targets in the context of Action 9 'Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)’. The actions contained 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 and CCU clusters, including feasibility for a European hydrogen infrastructure (targets 2 & 3 and 10)

**R&I Activity 3**: EU Projects of Common Interest for CO2 transport infrastructure (target 4)

**R&I Activity 4**: Establish a European CO2 Storage Atlas (target 5)

**R&I Activity 5**: Advancing European Storage capacity (target 7)

**R&I Activity 6**: Developing next-generation CO2 capture technologies (target 6)

**R&I Activity 7**: CCU Action (targets 8 & 9)

**R&I Activity 8**: Understanding and communicating the role of CCS and CCU in meeting European and national energy and climate change goals (target 10)

# Flagship activities

A number of Flagship Activities 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 project: Delivery of ROAD**

This will be the first application of CCS in the power sector in Europe and will enable visibility on costs of CCS and provide experience/cost reduction that can support subsequent phases of CCS. In addition, successful delivery of the ROAD project will demonstrate how existing coal power plants could be retrofitted with CCS.

**Flagship activity: Establish a CCS hub/cluster (including projects in the Netherlands, Norway and/or the UK)**

A number of CCS clusters are currently being progressed in SET-Plan countries, linking CO2 emissions-intensive industries. These clusters may also be supported by the development of pan-European CO2 infrastructure through the establishment of a Project of Common Interest.

**Flagship project: Fos-Berre/Marseille CCU cluster**

The Fos-Berre/Marseille CCU cluster aims sustain the industries in the region by reducing their CO2 emissions, as well as create new ties in sustainable development economics (water treatment, algae remediation), with further evaluation of the opportunities available for offshore storage.

**Flagship activity: Progress Projects of Common Interest (PCIs)**

The establishment of a Projects of Common Interest (PCI) under the 2017 European Commission call may act as a starting point for pan-European CO2 transport infrastructure, also supporting the development of regional CCS and CCU clusters.

**Flagship activity: Establish a European Storage Atlas**

The establishment of a European Storage Atlas will assist project developers and relevant permitting authorities to prioritise the most prospective areas for both onshore and offshore CO2 storage, and will enable the design and development of transport infrastructure to be optimised.

**Flagship Activity: Storage appraisal, with a pilot project**

Storage appraisal activities will build on the prospecting opportunities identified in the European Storage Atlas, with the aim of expanding European experience of CO2 storage, considering a range of storage options and injection volumes.

# R&I Activity 1: Delivery of the ROAD project

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

## Overview of existing and planned activities

*Delivery of the ROAD project (Flagship Project)*

The Rotterdam capture and storage project – abbreviated ROAD – will be a full-chain CCS project storing CO2 captured at a coal-fired power plant at Maasvlakte in the Port of Rotterdam. The Dutch government has provided €150 million of funding to facilitate the project. The project also has €180 million of funding from the European Energy Programme for Recovery (EEPR) fund. The project plan has undergone a number of changes since the project was first designed, including a change of storage location. A final investment decision (FID) was planned for the end of 2017 by the ROAD partners, and is now dependant on a number of National political factors.

*Progress of the Port of Rotterdam CCS and CCU cluster and other actions which may assist the ROAD project*

Delivery of the ROAD project will be aided by the Rotterdam CO2 hub at the Port of Rotterdam. The Port of Rotterdam is well positioned for the development of a Western Europe CO2 Hub, connecting offshore storage fields with emissions from Dutch heavy industry, and potentially other regions, including Antwerp, the Ruhr region in Germany.

## Identified gaps

To date only one CCS power project has been identified in SET-Plan countries which can be delivered by 2020. This creates risks to the delivery of Target 1 in the event that the project does not proceed. To increase the robustness of deliverables under R&I Activity 1, supporting the application of CCS in the power sector, it will be necessary to progress development on a number of additional projects. Although these projects would not be operational before 2020, there is still significant development work which could take place in the intervening period, including initial feasibility studies for the additional CCS projects in the power sector required to meet the 2030 targets outlined in the Declaration of Intent, outlined further below.

## Pathway to 2030 and beyond

To realise the 2030 Declaration of Intent KPIs[[4]](#footnote-4) of 10 commercial scale CCS projects in the power sector it is necessary to commence delivery of the next generation of projects, particularly those aimed at retrofitting existing power plants, and projects located in planned regional CCS and CCU clusters (see R&I Activity 2). The development of CCS projects in the power sector can take 7 to 10 years. Therefore, in order to realise 2030 objectives work on additional projects must be progressed as soon as possible, including an assessment of the opportunities available to retrofit existing assets in the power sector.

## Table 1a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanisms** |
| *Target 1:* At least one commercial-scale, whole chain CCS project operating in the power sector | * Completion of ROAD FID by 2017
* Full-chain CCS project in the power sector operational by 2020
* Establishment of a joint Horizon 2020 project to commence the delivery of the next generation of projects in the power sector
 |
| **Pathway to 2030 and beyond** | **Monitoring mechanisms** |
| 10 commercial scale CCS projects in the power sector | * Progression of the next generation of CCS projects in the power sector
* Policies established to support application of CCS in the power sector, linking to recommendations under R&I Activity 8
* Assessment undertaken of the opportunities available to retrofit further assets in the power sector
 |

## Expected deliverables and timeline

*Delivery of the ROAD project:*

This will be the first application of CCS in the power sector in Europe and will enable visibility on costs of CCS and provide experience / cost reduction that can support subsequent phases of CCS. In addition, successful delivery of the ROAD project will demonstrate how existing coal power plants could be retrofitted with CCS. This will achieve the following deliverables towards Target 1:

* Establishment of a joint Horizon 2020 project in **2019** [ongoing].
* Full-chain ROAD project operational by **2020** [ongoing].
* Assessment of opportunities to retrofit existing assets by **2020** [ongoing].

*Progress of the Port of Rotterdam CCS and CCU cluster and other actions which may assist the ROAD project:*

The Port of Rotterdam Authority will work with ROAD to support CCS and CCU developments, and initial parts of the cluster are expected to be operational by **2020/21** [ongoing]. Once operational this will deliver the following:

* Create an open backbone CO2 pipeline in the Port of Rotterdam, in order to connect Offshore Storage fields, Users of CO2 and Sources of CO2
* Connecting sources/companies capturing CO2 to a shared ‘CO2 backbone’ pipeline
* Connecting Offshore Storage fields with the Port (Connection area / interface between land/port and sea)
* Re-use of CO2 in order to attract strategic investment from 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 CO2 footprint

The ROAD project and subsequent CCS projects will be further assisted by the removal of certain legislative and administrative barriers. One such example is the Dutch Mining Law, which was amended in 2016 and came into effect on 1st January 2017, enabling simultaneous hydrocarbon production and permanent CO2 storage in the same reservoir at the same time. This progress will address some of the existing barriers to CCS and build experience with the regulatory framework and will support the development of subsequent CCS projects to meet 2030 targets [ongoing].

## Table 1b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Delivery of the ROAD project*  |
| European Commission | European Energy Programme for Recovery (EEPR) | €180 million*STATUS: Confirmed* |
| Member States and the European Commission | Horizon 2020  | Up to €60 million The European Commission proposes this project for the Horizon 2020 Energy Work Programme for 2018/19, with several countries already being committed to financially contribute.*STATUS: Proposed* |
| Dutch Government  | State funding | €150 million*STATUS: Confirmed* |
| GCCSI | Funding agreement | €4.3 million*STATUS: Confirmed* |
| Uniper and Engie (owners of the ROAD Project) | Private funding  | €100 million (€50 million each)*STATUS: Proposed* |
| Port of Rotterdam | Co-investor[[5]](#footnote-5) | €15 million*STATUS: Confirmed* |
| *Progress of the Port of Rotterdam CCS and CCU cluster*  |
| See ‘Financing of planned activities to 2020’ table under R&I Activity 2: Delivery of regional CCS and CCU clusters, including feasibility for a European hydrogen infrastructure | **Total budget required:** €485-520 million *(excluding contributions from the Port of Rotterdam)* |

## Table 1c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| Regional concepts developed to identify prospective CCS power projects which may be progressed, particularly opportunities to retrofit existing assets. | Mixture of private sector, national and EU instruments can be used to progress developments.  | Funding for 5-10 pre-FEED studies for CCS projects in the power sector. Estimated cost of around €8–14 million per study.*STATUS: Proposed* |
| Member States, private sector, European Commission | State fundingConnecting Europe FacilityInnovation Fund | CCS projects will be eligible for funding under a future EU ETS Innovation Fund, with the detailed rules for this fund currently being developed. *STATUS: Proposed* |
| R&D actions | EERA CCS (and others) to supply input | *STATUS: Proposed* |
|  |  | **Total budget required: xxx** |

# R&I Activity 2: Delivery of regional CCS and CCU clusters, including feasibility for a European hydrogen infrastructure

Responds to ***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), and* ***Target 10****: By 2020, Member States having delivered as part of the Energy Union Governance their integrated national energy and climate plans for after 2020, 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.*

## Overview of existing and planned activities

*Norwegian CCS cluster*

The ambition of the Norwegian Government is to build a full scale CCS demonstration project, operational by 2022. Feasibility studies have been concluded and conceptual studies started in 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 pipeline and ship transport of CO2 and Statoil has studied three sites on the Norwegian Continental Shelf for storage.

*Rotterdam CCS and CCU cluster*

The planned Rotterdam CO2 hub at the Port of Rotterdam will collect emissions from industrial sources and transfer and store these offshore in the North Sea, with significant synergies with the ROAD project (see R&I Activity 1). It is hoped that the hub will be the starting point for large-scale CCS in the region, connecting all large CO2 point sources in the Rotterdam area, as well as also benefiting more distant CO2 point sources, including Antwerp and Germany. There are also plans for CCU applications to be developed, including for enhanced oil recovery (EOR) and greenhouses. The Port of Rotterdam is currently working on a concrete plan for CCS from industrial sources, with an initial connection to at least 1 industrial source to launch the pipeline.

*UK East Coast CCS cluster*

A UK East Coast CCS cluster 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 CO2 to use a common transport and storage infrastructure. Following a feasibility study an early phase project is proposed, which would capture and store 11 million tonnes of CO2 over 15 years. This network could then be expanded to capture 10 million tonnes of CO2 per year as power stations and further industrial companies join the network.

*Le Havre CCS cluster*

The Le Havre Harbour area emits around 10 MtCO2/year. A European FP7 project - COCATE - aimed to evaluate the cost of capture and clustering the CO2 emissions for pipeline and ship transport towards the Rotterdam area and the North Sea. Since then several projects on CO2 capture and hydrogen have been deployed in the territory.

*Fos-Berre/Marseille CCU cluster (Flagship Project)*

The Fos-Berre/Marseille Industrial area currently emits about 13 MtCO2/year, with a current objective to find synergies between industrial emitters and potential CO2 utilisation pathways. The project’s aim is to sustain the industries in the area by reducing their CO2 emissions, as well as create new ties in sustainable development economics (water treatment, algae remediation) and evaluate opportunities for offshore storage. The study is based on a collection of emission data and an analysis of the evolution scenarios of the various industrial sectors in the Fos-Berre-Beaucaire-Gardanne area.

*Feasibility for a European hydrogen infrastructure*

A European hydrogen infrastructure, combining CCS and hydrogen produced either through the pre-combustion processing of hydrocarbons through Steam Methane Reforming (SMR) or electrolysis using renewable energy, could create options to replace the use of fossil fuels for transport, industry, heating, and cooking applications. This production would take place in large-scale plants and be distributed through existing infrastructure serving CCS applications. There is also the option to use hydrogen, along with captured CO2 to produce fuels and chemicals, such as methanol, linking to actions identified under R&I Activity 7 (CCU Action).

The CO2 emissions generated from the hydrogen production process can be captured (by pre-combustion capture technologies) and stored. This also provides opportunities to limit emissions from many small emission sources where CO2 capture is impractical. There are no technical barriers to large-scale hydrogen production; however, further assessment is needed to improve the understanding of the possibilities and limitations (including potential safety aspects) of using existing infrastructure for the transport and use of hydrogen-enriched natural gas. Also important will be understanding the possible environmental and climate related benefits and trade-offs where hydrogen replaces fossil fuels, including an assessment of the sustainability and CO2 abatement potential for the various hydrogen production options and uses. In addition, process intensification, process integration and emerging new capture technologies should be investigated to obtain more efficient and economic solutions for hydrogen production.

## Identification of gaps

The Norwegian CCS cluster is making good progress, with a FEED study currently underway. However, the remaining clusters proposed are currently at differing stages of development. In order to realise the 2030 Declaration of Intent KPI - to have a minimum of 5 commercial-scale CCS projects in the CO2 emission intensive industries - then progress on further CCS and CCU clusters is required. By 2020 the remaining 4 clusters should aim to have completed pre-FEED studies, in addition to completed concept development and cost studies.

At present the CCS and CCU clusters being progressed are concentrated in Western Europe, with a particular focus around the North Sea Basin. To achieve greater geographical distribution of CCS and CCU clusters within Europe feasibility studies considering options in Eastern European regions. This could involve onshore or offshore storage of CO2, and could further benefit from a separate ship transportation feasibility study, building on work in this area by Norway and the UK[[6]](#footnote-6). This may provide a route for the cross-border transport of CO2 from additional industrial CCS and CCU clusters to storage sites where indigenous storage is not available. To enable this 2-3 additional feasibility studies, should be initiated by 2020. These studies may proceed alongside proposed actions under Activities 4 and 5 (Establish a European CO2 Storage Atlas and CO2 storage pilots in operation), also benefiting from the proposed ship transportation feasibility study.

## Pathway to 2030 and beyond

Realising the 2030 Declaration of Intent KPI target to have a minimum of 5 commercial-scale CCS projects in the CO2 emission intensive industries and 10 projects in the power sector requires the delivery of the 5 CCS clusters already being progressed, with all projects at least reaching the FEED study and then construction stage in the early to mid-2020s. In addition, a further 2 to 3 additional CCS and CCU clusters should be initiated, preferably located in Eastern Europe.

## Table 2a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
|  **DOI Target** | **Monitoring mechanism** |
| *Target 2:*At least one commercial scale CCS project linked to an industrial CO2 source, having completed a FEED study | *Norwegian CCS cluster:* * Completion of FEED study on Norwegian CCS cluster by 2019
 |
| *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) | *Rotterdam, UK East Coast, Le Havre, and Fos-Berre/Marseille CCS and CCU clusters:* * Rotterdam CCS and CCU cluster completed feasibility and FEED studies by 2020 (with the expectation to be operational in 2020/21) [ongoing]
* UK East Coast CCS cluster completed feasibility study and ready to begin FEED study by 2020 [ongoing].
* Le Havre CCS cluster completed feasibility study and ready to progress with FEED study by 2020 [ongoing]
* Fos-Berre/Marseille CCS and CCU cluster completed feasibility study and ready to progress with FEED study by 2020 [ongoing]

*Feasibility studies for further industrial CCS and CCU clusters* * To achieve geographical balance of CCS and CCU clusters feasibility studies for 2-3 regions, including onshore and offshore storage options or ship transport, have been completed, with at least 1 progressing to pre-FEED stage beyond 2020

*Feasibility for a European hydrogen infrastructure** Study undertaken into the feasibility of a European hydrogen infrastructure
* Inclusion of feasibility for a hydrogen infrastructure topic in the Horizon 2020 2018/19 Energy Work Programme
 |
| *Target 10:* By 2020, Member States having delivered as part of the Energy Union Governance their integrated national energy and climate plans for after 2020, 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 | *Norwegian, Rotterdam, UK East Coast, Le Havre, and Fos-Berre/Marseille CCS and CCU clusters:* * Assesment of the socio-economic benefits of CCS and CCU clusters undertaken

*Feasibility for a European hydrogen infrastructure** Assessment of the sustainability and CO2 abatement potential for the various hydrogen production options and uses
 |
| **Pathway to 2030 and beyond** | **Monitoring mechanism** |
| 5 commercial-scale CCS projects in the CO2 emission intensive industries | *Norwegian, Rotterdam, UK East Coast, Le Havre, and Fos-Berre/Marseille CCS and CCU clusters:* * Norwegian CCS cluster operational by 2022
* Multiple CCS and CCU clusters moving into FEED and construction in the early to mid-2020s.
* Completed ship transport feasibility study, building on previous work done by Norway and the UK, which can provide options for feasibility studies of industrial CCS and CCU clusters in regions without access to CO2 storage resources.

*Feasibility studies for further industrial CCS and CCU clusters* * Having completed feasibility studies the most promising CCS and CCU clusters have been progress to pre-FEED stage.

*Feasibility for a European hydrogen infrastructure** One or more early hydrogen infrastructure projects being developed
 |

## Expected deliverables and timeline

*Norwegian CCS cluster:*

* Completion of FEED study for Norwegian industrial CCS cluster in **2019** (with the aim to be operational by **2022)** [ongoing].

*Progression of Rotterdam, UK East Coast, Le Havre, and Fos-Berre/Marseille CCS and CCU clusters:*

In order to meet Target 3, a further 4 of the industrial CCS and CCU clusters listed on page xxx need to have at least reached pre-FEED stage, and be ready to begin FEED studies:

* By **2020**, all 5 industrial CCS and CCU clusters have completed pre-FEED studies and are ready to progress to FEED stage.

*Feasibility for further industrial CCS and CCU clusters:*

A further 2 to 3 regions with the potential to develop industrial CCS and CCU clusters need to be identified and advanced for feasibility studies, with consideration of geographical balance. Selection of additional industrial CCS and CCU clusters should attempt to achieve a greater geographical distribution of CCS and CCU projects, beyond the North Sea Basin. The feasibility and FEED studies, as well as the implementation of the clusters, will require support from Member States, industry and the European Commission, with funding through the Innovation Fund [proposed].

* Feasibility studies completed for 2 to 3 additional industrial CCS and CCU clusters by **2020** [proposed]

*Feasibility for a European hydrogen infrastructure:*

The sustainability and CO2 abatement potential offered by the replacement of fossil-based hydrogen production options should be included within European and national energy and climate plans (see R&I Activity 8), towards achieving Target 10.

* Study undertaken into the feasibility of a European hydrogen infrastructure by **2020** [proposed].
* Assessment of the sustainability and CO2 abatement potential for the various hydrogen production options and uses by **2020** [proposed].
* Evaluation of potential for hydrogen to reduce CO2 emissions in the transport, heating, industrial and power sectors as part of national and international energy and climate plans by **2020** [proposed].

## Table 2b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Norwegian CCS cluster:* |
| Norwegian Government, Norcem AS, Yara Norge AS, Waste-to-Energy Agency in Oslo municipality, Gassco, Statoil. | State funding and private funding. | €800-1400 million of expected planning and investment costs, depending on how many sources from which CO2 will be captured.Status: Under development. Estimates based on feasibility study.*STATUS: confirmed* |
| *Rotterdam CCS and CCU cluster:* |
| Port of Rotterdam Authority, Relevant companies in Rotterdam Harbour Area, CO2 Smart Grid | More information required  | Total estimated costs €235 million for realisation of the backbone pipeline in the Rotterdam port area (connecting Maasvlakte with OCAP), 43 Mton storage field and 500kton CO2/yr next to ROAD project). *STATUS: proposed* |
| Netherlands Government | Roadmap for CCS in the Netherlands, to be developed in 2017, will include suitable instrumentation. |  |
| *UK North East CCS and CCU cluster:* |
| Teesside Collective, Tees Valley Combined Authority | Industrial funding  | Not yet determined *STATUS: proposed* |
| UK Government  | State funding  | Teesside Collective have asked the UK Government for £15 million for FEED studyFollowing Pilot study would cost £110 million to build and £29 million/year to run, and could be operational in 6 years. *STATUS: proposed* |
| *Le Havre CCS cluster:* |
| Parties involved? | Funding?State/private? | Cost? |
| *Fos-Berre/Marseille CCU cluster* |
| Parties involved? | Funding?State/private? | Cost? |
| *Feasibility studies for further industrial CCS and CCU clusters:*  |
| European Commission and National governments | Horizon 2020 2018/19 Energy Work ProgrammeInnovation Fund (planned under a reformed Emission Trading System/ETS)State funding | CCS and CCU projects will be eligible for funding under a future EU ETS Innovation Fund; detailed rules for this fund are currently being developed. It is expected that a further 2-3 feasibility studies for future European CCS and CCU clusters would cost €2-3 million.*STATUS: proposed* |
| *Feasibility for European hydrogen infrastructure* |
| Governmental CCS and CCU bodies, industry, both vendors and users, engineering companies, research organisations, academia, European Commission and Member States | Providing options for CCS and CCU clusters to develop hydrogen infrastructure will require support from the European Commission and a dedicated topic under the Horizon 2020 Energy Work Programme for 2018/19.  | €XX for R&D and pre-feasibility studies for future hydrogen infrastructure.*STATUS: proposed* |
| EERA CCUS | Contribute towards R&D actions |  |
|  |  | **Total budget required: xxx** |

## Table 2c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Feasibility studies for further industrial CCS clusters including ship transport feasibility study* |
| Industrial CCS and CCU clusters: European Commission, Member States, and private sector | Innovation Fund (planned under a reformed Emission Trading System/ETS) | CCS and CCU projects will be eligible for funding under a future EU ETS Innovation Fund; detailed rules for this fund are currently being developed. It is expected that a further 2-3 feasibility studies for future European CCS and CCU clusters would cost €2-3 million.  *STATUS: proposed* |
| Ship transport feasbility study: European Commission and Member States | Build on previous studies within Cintra, CATO-Climit etc.  | €xxx million made available for a ship transport feasibility study to allow for cross-border transport of CO2 and providing options to develop additional industrial CCS and CCU clusters in regions of Europe without access to storage resources. *STATUS: proposed* |
| *Feasibility for European hydrogen infrastructure* |
| Governmental CCS and CCU bodies, industry, both vendors and users, engineering companies, research organisations, academia, European Commission and Member States | European Commission funding – identify instrument State funding  | €xxx for development of one or more early hydrogen infrastructure projects *STATUS: proposed* |
|  |  | **Total budget required: xxx** |

# R&I Activity 3: EU Projects of Common Interest (PCI) for CO2 transport infrastructure

Responds to ***Target 4:*** *At least 1 active EU Project of Common Interest (PCI) for CO2 transport infrastructure, for example related to storage in the North Sea*

## Overview of existing and planned activities

*Progression of at least 1 EU Project of Common Interest*

Reaching long-term European climate targets requires wide CCS deployment. In the second half of this century, the magnitude of CO2 stored should be in the order of hundreds of million tonnes CO2 annually. This will require a large pan-European CO2 transport infrastructure that links CO2 sources and sinks in a cost effective way, as well as potentially supporting CCU applications. In order to ensure that the CO2 transport infrastructure is available in due time planning needs to start before 2020.

The European Commission has established an instrument to accelerate infrastructure development called Projects of Common Interest (PCI). The ambition is that PCIs should contribute to complete the European internal energy market and to reach the EU's energy policy objectives of affordable, secure and sustainable energy. PCIs can apply for financial support through the Connecting Europe Facility (CEF), with the most recent opportunity for PCI selection being early-2017, with such funding intended to accelerate the projects and attract private investors.

The PCI instrument could be the starting point for pan-European CO2 transport infrastructure. Actions must start already in 2017 to ensure that a new PCI on CO2 transport infrastructure can be established. The process for applications for PCI status and access to Connecting Europe Facility (CEF) is currently underway, with successful projects expected to be announced in mid-2017. Therefore, there is a need to review and update actions under this activity once the PCI list is finalised.

In some instances the timely re-purposing of existing petroleum infrastructure may achieve cost reductions for first-of-a-kind projects, particularly where this re-purposing can be achieved rapidly. The potential cost-benefits and opportunity windows need to be well understood, in addition to actions which may be required to preserve strategically important infrastructure at risk of decommissioning and removal.

One project which plans to repurpose existing infrastructure is the planned UK Acorn CCS project, which submitted an application to the latest PCI call. Acorn will initiate a low cost full chain CCS project in the North East of Scotland. This will act as a seed (acorn) from which to grow a cluster of capture, transport and storage infrastructure which will contribute significantly to the commercial decarbonisation of the region. Infrastructure can be further developed by adding additional CO2 capture points, such as from hydrogen manufacture for transport and heat, future CO2 shipping through Peterhead Port to and from Europe, and connection to UK national onshore transport infrastructure such as the FEEDER 10 pipeline which can bring additional CO2 from emissions sites in the industrial central belt of Scotland including the proposed Caledonia Clean Energy Project.

Together with major stakeholders, the Dutch parties have submitted a proposal for a PCI with a modular CO2 transport infrastructure that connects the Rotterdam harbour to storage reservoirs in the Dutch and UK sections of the North Sea. A first step can be a feasibility study including CO2 sources in the Rotterdam and map them with storage options in the North Sea. A feasibility study would include a study of scaling up CCS in the Rotterdam industrial cluster. The initiative could team up with the Flemish (Port of Antwerp) and potentially German partners.

The North Sea Basin Task Force (NSBTF) has developed the “North Sea Strategic Regional Plan”, with the primary purpose of assisting bids for PCI projects. The NSBTF is composed of public and private bodies from countries around the perimeter of the North Sea. The NSBTF recognises that the North Sea Basin is the most logical place in Europe to start transport and storage of CO2 and that the countries bordering the North Sea need to coordinate and plan together to deliver an optimum network. North Sea Basin Task Force also encourages collaboration between PCIs. An example is the ongoing Norwegian CCS initiative (an expected deliverable under R&I Activity 2), which aims to build storage capacity, in excess of the need for storage volumes in the current project. Additionally, Statoil has submitted an application for PCI on the concept of CO2 transport from point sources in the UK and the Continent to the storage site on the Norwegian Continental Shelf by ship.

The Horizon 2020 funded Gateway project is a first step towards deployment of CCS through a cross-border CO2 transport infrastructure, providing a strategic decision basis to enable all stakeholders to identify and implement measures that can accelerate deployment of technologies needed for realisation of large-scale CCS projects based on European CO2 transport infrastructure. It is expected that one PCI submitted will build on recommendations established by the Gateway project.

## Identification of gaps

Delivery of a CO2 PCI by 2020 requires established regulatory framework for applications. This is being coordinated by DG Energy but any delays in announcing the status of projects which have submitted an application or their subsequent access to the CEF could result in Target 4 being undeliverable. If prospective projects are unable to put in an application at this stage this next call for PCI status will not take place until 2019.

The London Protocol prohibits the export of CO2 from a contracting party to other countries for injection into sub‐seabed geological formations. The protocol was amended in 2009 to enable cross‐border CCS projects, but the amendment must be ratified by two‐thirds of contracting parties to enter into force. Given the required number of ratifications and difficulties associated with the ratification process, it appears unlikely that two‐thirds of contracting parties will be in a position to ratify the amendment in the near term. Raising awareness among relevant government ministries of the importance to global CCS deployment of ratifying the London Protocol amendment should be a priority. Consideration should be given to options identified by the International Energy Agency[[7]](#footnote-7) that may be available to contracting parties under international law to address this barrier to CCS deployment pending formal entry into force of the 2009 amendment.

## Pathway to 2030 and beyond

At least one of the projects awarded PCI status in the current application round takes a positive investment decision and is constructed. This project will be an enabler for subsequent projects by testing the regulatory and legal framework, and successfully navigating any potential issues which arise. The development of cross-border CCS projects can be enablers for projects in countries without access to indigenous CO2 storage resources thereby broadening the range of countries that can benefit from the development of CCS.

## Table 3a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanism** |
| *Target 4:* At least 1 active Project of Common European Interest for CO2 transport infrastructure, for example related to storage in the North Sea.  | * At least 1 projects awarded PCI status in 2017 application round (including Acorn, Rotterdam CCS and CCU cluster, Norwegian CSS cluster).
* Delivery of the Gateway project in2017 providing a comprehensive integrated PCI project proposal providing a model for establishing European CO2 infrastructure
* Successful PCI project/s have access to funding through the Connecting Europe Facility in 2018
* Continuation of NSBTF work to building collaboration between PCI projects
 |
| **Pathway to 2030 and beyond** | **Monitoring mechanism** |
| At least 1 PCI project from 2017 application round undertakes FID and is developedFurther projects apply for PCI status under 2019 call for applications | * Application of further PCI projects as part of 2019 call for applications for PCI status.
* Projects in regions without CO2 storage options enabled through ship transport feasibility study, identified under R&I Activity 2.
 |

## Expected deliverables and timeline

*Progression of at least 1 European Project of Common Interest*

The Dutch and UK government has already taken a key role to establish the PCIs. Other MS and associated countries close to the North Sea should also engage in this work. NSBTF will also play a key role. Other MS should engage to identify the possibilities for PCIs in other areas than the North Sea. Continuation of the ongoing support from European Commission will be essential.

* At least 1 of the projects submitted to the 2017 application call on CO2 transport infrastructure is awarded PCI status, in **2017** and access ensuring to funding through the CEF mechanismby **2018** [ongoing].
* Further applications for PCI projects under **2019** call [proposed].

## Table 3b: Financing of planned activities to 2020 (this will be updated once the 2017 PCI list is finalised)

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Progression of at least 1 European Project of Common Interest*  |
| Dutch Government UK Government Norwegian Government  | National Government programmes and funds | *STATUS: proposed* |
| European Commission  | Connecting Europe FacilityHorizon 2020 2018/19 Energy Work Programme | *STATUS: confirmed* |
| EERA CCS  | Contribution on *R&D Actions* |  |
| *Gateway Project*  |
| European Commission | Horizon 2020  | €787,000*STATUS: confirmed* |
|  |  | **Total budget required: xxx** |

## Table 3c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Development of at least 1 of the European Project of Common Interest awarded funding under the 2017 call*  |
| Dutch Government UK Government Norwegian Government  | National Government programmes and funds | *STATUS: proposed* |
| European Commission  | Connecting Europe FacilityHorizon 2020 2018/19 Energy Work Programme | *STATUS: proposed* |
| EERA CCS  | Contribution on *R&D Actions* |  |
| *Progression of European Projects of Common Interest under the 2019 funding call*  |
| National Governments and Industry  | National Government programmes and funds | *STATUS: proposed* |
| European Commission  | Connecting Europe FacilityHorizon 2020 2018/19 Energy Work Programme | *STATUS: proposed* |
| EERA CCS  | Contribution on *R&D Actions* |  |
|  |  | **Total budget required: xxx** |

# R&I Activity 4: Establish a European Storage Atlas

Responds to ***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*

## Overview of existing and planned activities

A European CO2 Storage Atlas identifying and characterising all recognised prospective storage sites on a consistent basis is needed to facilitate site comparison, site ranking, and integrated regional or national planning of storage and transport development. The atlas will greatly assist project developers and relevant permitting authorities to prioritise the most prospective areas for both onshore and offshore CO2 storage, and will enable the design and development of transport infrastructure to be optimised.

Several assessments of European storage have been made, the most recent version being the CO2StoP Atlas. This atlas is to be released in 2018 via EC JRC and will be embedded in the EuroGeoSurveys[[8]](#footnote-8) European Geological Data Infrastructure (EGDI). However, although this atlas builds on preceding projects such as EU GeoCapacity and particularly CO2 SToP, it has been superseded in certain European countries which have completed significantly more detailed assessments and databases of their storage resources.

An updated European Storage Atlas will create and adopt, as appropriate, best practice which might include the Storage Resource Management System being developed by the Society of Petroleum Engineers, building on existing storage assessments, which can include the Norwegian Petroleum Directorate Storage Atlas published in 2014, the Nordic CO2 Storage Atlas published in 2015, and the Strategic UK CO2 Storage Appraisal Project (CO2 Stored) published in 2016. The aim will be to develop consistent and comparable estimates of European storage capacity to enable site selection for further detailed appraisal and strategic planning of transport and storage infrastructure.

A European Storage Atlas will be the foundation from which a strategic portfolio of ‘bankable’ stores can be developed. It will not however, provide this portfolio by itself as each store will require more detailed project-specific characterisation, appraisal, design and permitting, such as through the actions outlined under R&I Activity 5. However, these storage appraisal activities may further validate storage assessments in different geological settings within the European Storage Atlas.

## Identified gaps

Initiating work programmes to establish a storage atlas, comparing advanced work in this area, such as that completed by the UK and Norway in order to ensure an agreed set of methodologies is adopted. In order to maximise the value of early efforts this should focus on regions identified under R&I Activity 2 of the Implementation Plan. Later efforts should focus on developing a wider storage atlas to facilitate CCS across Europe. In addition, a European body needs to be needs to be identified which can host the Atlas and facilitates its regular updating.

## Pathway to 2030 and beyond

A process will be put in place to ensure that the Atlas is reviewed and updated, this should also link to delivery of the storage pilot projects outlined in R&I Activity 5.

Continued development is needed to expand the initial storage atlas towards a comprehensive Europe-wide atlas, with periodic reviews of the approach to ensure best-practice.

## Table 4a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanism** |
| *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 | * Agreement on a staged methodology for the determination of storage capacity at different levels of detail
* Agreement on, and implementation of, an organisational structure
* Completion of Storage Resource Management System, currently being developed by the Society of Petroleum Engineers, and study undertaken to contract with existing UK approaches.
* Delivery of a storage atlas based on an agreed set of methodologies for member states and regions to meet CCS policies and plans, including the expected CO2 supply from clusters of emitters.
* Methodologies to consistently evaluate storage capacities will be defined, including risk and liability assessments and techno-economic assessments, in addition to geotechnical assessments.
* Identification of an existing, or create a new pan-European body to collect and coordinate storage information on a regular basis.
 |
| **Pathway to 2030 and beyond** | **Monitoring mechanism** |
| Expansion of European Storage Atlas  | * Identification and inclusion of storage resources beyond the initial study of regions identified in R&I Activity 2.
 |

## Expected deliverables and timeline

The establishment of a European Storage Atlas will deliver the following:

* Agreement and implementation of an organisational structure by **2018** [proposed].
* Collation of National storage assessments to produce a European Storage Atlas, to be completed and released in **2020**.
* Collation of national storage assessments to produce an updated European Storage Atlas based on an agreed set of methodologies for member states and regions to meet CCS policies and plans, including the expected CO2 supply from clusters of emitters to be completed and released in**2020** [proposed].
* Release of European CO2 storage atlas (CO2StoP Atlas) in **2018**
* Fit-for-purpose (i.e. matched to potential CO2 capture rates) estimates of storage capacities, based on simulations of credible capture, transport and injection scenarios. Agreement on a set of methodologies for storage capacity determination in **2018**.
* An online, freely accessible, decision support system (webGIS) that allows potential site developers to obtain basic geological information on potential sites.
* Support of appraisal activities carried out as part of R&I Activity 5.

## Table 4b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Establish an updated European Storage Atlas* |
| Collaboration between EuroGeoSurveys, ENOS project Consortium, CO2GeoNet, JRC-European Commission, ENeRG with support from the European Commission, Norwegian, UK Dutch, and German Governments, Statoil, and CCS project consortia throughout Europe. | State fundingIndustry fundingHorizon 2020 2018/19 Work Programme | Up to €10 million needed for further appraisal in selected regions and completion of the atlas and additional funding for future updates and online operations of the atlas.*STATUS: proposed* |
| NSBTF- process will join up the existing storage assessments for the North Sea region. | More information required | More information required*STATUS: confirmed* |
| *Other existing or recent activities and National storage studies which could be incorporated into a storage atlas, subject to procedures to ensure consistent reporting of estimations:*  |
| Limited work on storage capacity methodology and determination ongoing in H2020 ENOS project (WP2) | Funding?  | Cost? |
| Norwegian Petroleum Directorate Storage Atlas- database was published in 2014 and provides ongoing information for future exploration for CO2 storage sites. [completed] | State funding | Cost?*STATUS: confirmed* |
| Building Nordic Excellence In CCS (NORDICCS – The Nordic CCS Competence Centre, published interactive storage atlas and report in 2016.  | State funding | €1.2 millionFunded by Top Level Research Initiative (TRI)/ Nordic Innovation*STATUS: confirmed* |
| Strategic UK CO2 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.  | State funding | £4 million spent on the Strategic UK CO2 Storage Appraisal Project. Detailed appraisal of 5 stores from a portfolio of 20 ‘high-ranked’ potential sites in the UK was achieved with a further £1m. *STATUS: confirmed* |
| Speicherkataster Storage Catalogue of Germany- published open access in 2011  | State funding | Speicherkataster Storage Catalogue of Germany- €1.067 m state funding; €0.3 m private funding*STATUS: confirmed* |
| Netherlands CO2 Transport and Storage Plan  | State funding | Netherlands CO2 Transport and Storage Plan will be funded by the Dutch Government*STATUS: confirmed* |
| FENCO Utsira Aquifer (Germany) Analysis of potentials and costs of CO2 storage in the Utsira aquifer in the North Sea  | State funding | € 0.178 million State spent on FENCO Utsira Aquifer (Germany) Analysis*STATUS: confirmed* |
| EuGeoCapacity, CASTOR, GESTCO, Joule II. | State funding | Estimated € 6-7 million from FP6 and FP7 spent*STATUS: confirmed* |
| TUBITAK KAMAG Project Assessment of CO2 emissions from industrial sites, potential for underground storage in Turkey and modelling of storage in an oil field. Completed in 2009.  | Funding?  | Cost?*STATUS: ?* |
| BASRECCS CO2 storage assessment in the Baltic region | Funding? | Cost?*STATUS: ?* |
|  |  | **Total budget required: xxx** |

## Table 4c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Expansion and updates of European Storage Atlas* |
| EuroGeoSurveys, ENOS project Consortium, CO2GeoNet, JRC-European Commission, ENeRG with support from the European Commission, Norwegian, UK Dutch, and German Governments, Statoil, and CCS project consortia throughout Europe. | State fundingIndustry fundingCommission funding? | Cost to expand/maintain around €10 million  |
|  |  | **Total budget required: xxx** |

# R&I Activity 5: Advancing European Storage Capacity

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

## Overview of existing and planned activities

Work has already been undertaken to produce a comprehensive storage atlas that can inform the future development of CO2 storage sites (see R&I activity 4, creation of a European Storage Atlas). Initial projects, planned under R&I activities 1-3, can be used to support the validation of the storage potential undertaken as part of R&I Activity 4. All SET-Plan countries should establish national transport and storage plans and by aligning these national plans it will be possible to identify CO2 storage projects that could be established as joint European storage projects on the basis of their importance to European CCS development.

Actions under this R&I Activity will build on a number of ongoing and completed projects. This includes a study by Pale Blue Dot Energy in 2015 to deliver an open access screened and appraised portfolio of offshore geological CO2 storage sites for potential deployment in future CCS projects. The project for the then UK Department for Energy and Climate Change and the Energy Technologies Institute involved a detailed appraisal of five CO2 storage sites, facilities concept design and costing and economics.[[9]](#footnote-9)

To contribute to target 7, the storage projects developed should contribute to the criteria listed below;

* Storage sites with expected annual injection in the range of 1000 -100,000 tCO2 p.a.
* The CO2 storage projects should support large-scale storage, include both onshore and offshore projects, and be ‘scalable’ i.e. be capable of leading to full-scale transport and storage. Identification of ways in which projects may contribute to actions under R&I Activities 1, 2, and 3.
* Small-scale CO2 storage projects should employ and verify new monitoring and visualisation technologies Pilot on CO2 storage as part of CO2 EOR operations. Developing this aspect of CCS and CCU could provide an important component in building a future business model. Most of the current European potential for CO2 EOR is offshore in the North Sea, but an onshore pilot may be carried out in a number of European member states, including at the Czech LBr1 site.

A number small-scale storage projects have been identified which may support these outcomes, included in Annex (ref and pg number).

## Identified gaps

An assessment of existing and proposed projects is required to identify those which can deliver on the criteria outlined above. If none of the projects listed in Annex (ref page number) are able to deliver the actions required under Target 7 new storage projects need to be identified and progressed.

## Pathway to 2030 and beyond

A process needs to be put in place by which information from small-scale storage projects may feed into storage assessments and the European Storage Atlas produced as part of actions under R&I Activity 4 of the Implementation Plan.

## Table 5a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanism** |
| *Target 7:* At least 3 new CO2 storage pilots in preparation or operating in different settings | * Portfolio of identified opportunities (ENOS deliverable in 2018)
* Funding awards and projects commissioned
* Designs completed for small-sale storage projects covering range of geological and geographical contexts.
* At least 3 small-scale storage projects commissioned.
 |
| **Pathway to 2030 and beyond** | **Monitoring mechanism** |
| 15 permits for CO2 storage in Europe | * The most promising storage projects listed in Annex will be progress, and additional projects identified and developed.
 |

## Deliverables and timeline

Parties most appropriate to deliver small-scale storage projects would be potential storage project developers (oil and gas companies and associated engineering firms) that would be supported by the CO2 storage research community. This will deliver the following outcomes:

* Expand European experience of CO2 storage across a range of storage options
* Development of at least 3 full-scale storage projects, covering a range of storage options by **2020** [ongoing]
* Appraisal of most promising storage resources identified in the European Storage Atlas (R&I Activity 4) by **2020** [ongoing]
* Improved understanding of monitoring and visualisation, and how to cost-effectively meet the requirements of the CCS Directive by **2020** [ongoing].

In addition a number of further projects listed in Annex (ref and pg number) will be progressed, contributing to Target 7.

## Table 5b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Advancing 3 storage projects*  |
| National GovernmentsIndustry European Commission | State fundingInnovation Fund  | Costs for small-scale storage projects expected to be between €5-10 million for construction onshore (increased where construction is offshore), excluding CO2 supply. *STATUS: proposed* |
| ZEP and EERA |  Coordination and promoting |  |
| R&D actions | EERA JP CCS to give input |  |
| *Continuation of activities at TCM* |
| Norwegian Government  | Norway Grants 2014-2021  | More information required |
|  |  | **Total budget required: xxx** |

## Table 5c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Parties** | **Implementation Instruments** | **Indicative financing contribution** |
| *Developing 15 storage projects in Europe*  |
| The most promising storage projects listed in Annex will be progress, and additional projects identified and developed.  |  |  |
|  |  | **Total budget required: xxx** |

# R&I Activity 6: Developing next-generation CO2 capture technologies

Responds to ***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*

## Overview of existing and planned activities

Building industrial scale CCS projects will generate many new challenges that can best be solved by undertaking R&D in parallel with large-scale activities. An iterative process is needed where R&D projects address specific industrial challenges, with the results then implemented in large-scale projects. This may require networks where knowledge and experiences, as well as data gained, can be shared in a systematic way, and could include the following areas:

* Integration of CO2 capture systems in power or industrial plants
* Heat integration and other environmental control systems (SOx, NOx, H2S)
* Part-load operations and daily cycling flexibility
* The impacts of CO2 composition and impurities.
* Demonstration of novel capture technologies (advanced chemical looping and calcium looping systems, membranes, novel solvents and solid sorbents) at TRL6-7 for a range of industrial environments.

The data collected at the plants will be instrumental in validating and improving simulation tools, thus increasing the understanding of the process and help bringing costs down. A significant barrier to achieving open exchange of information, knowledge and experience is Intellectual Property Rights. The sharing may have to be limited to non-proprietary and generic data and environmental issues that the research and engineering communities can work on to bring costs down.

Within CO2 capture, pilots are needed to ensure fast and cost effective R&D activities. New and emerging capture technologies are at very different stages of maturity, ranging from concepts to larger projects, i.e. at 20-30MW, or a capture capacity of up to a few hundred thousand tonnes of CO2/yr. One challenge is to scale technologies from the concept stage to larger sizes as it requires large test facilities. Presently there are few large-scale test facilities and the existing ones are mainly for solvent-based post-combustion technologies. Development of novel capture technologies will benefit from international cooperation and burden sharing to establish a few large test facilities for other capture technologies in a network, building on the experiences from ECCSEL and from the existing base of pilots built under recent and ongoing EU research projects and from the International CO2 Test Centre Network (ITCN).

The large-scale test facilities exist from some process routes, such as the Technology Centre Mongstad (TCM) in Norway, one of the most advanced and the largest post-combustion CO2 capture pilots, where several vendors having already qualified their CO2 capture technologies. Onwards to 2020, TCM could play a key role by providing test campaigns for new and innovative post-combustion technologies that can realise the efficiency and cost-effectiveness of CO2 capture technologies in full-scale plants.

Recently the development of advanced, high-efficient supercritical CO2 (S-CO2) cycles using oxy-fired gas turbines is gaining an increasing interest worldwide as an advanced CO2 capture technology able to meet the load flexibility requirements needed in the energy transition scenario. Existing proven power generation equipment can be adopted for S-CO2 power cycle; however, research and development are needed for specific devices (i.e. high pressure oxy-combustor, water separation unit, heat exchangers) and or processes (i.e. purification of hot combustion gases, development of quick start-up strategies).

## Identified gaps

There is need for similar size facilities for other capture technologies as well as those tailored to test and commercialise capture technologies required for specific industries, for example cement and steel.

## Pathway to 2030 and beyond

Further innovation will require the creation of a demand for such novel CCS technologies by proving CCS as a decarbonisation via commercial scale demonstration projects and by developing incentives which provide a perspective for CCS; including these novel technologies to become commercial. In turn, this can then stimulate further innovation and learning through the creation of a competitive sector.

Collaboration should be initiated (and in some cases continued) between SET-Plan countries, the European Commission, and industry in ‘Innovative Consortia’, as well as the CCS and CCU clusters listed under R&I Activity 2, to drive forward the most promising technologies towards commercialisation.

## Table 6a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanism** |
| *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 | * Funding secured under the Horizon 2020 2018/19 Energy Work Programme
* Agreement on and implementation of large pilot test facilities for other capture systems than post-combustion
* Project proposals for testing the potential of sustainable Bio-CCS at TRL 6-7 which are in line with the sustainable development policies of the EU
* Pilots of emerging technologies tested at TRL5-7 and fitted to work with flue gas or boundary conditions, as present in large non-power industries.
* Identification of a platform to share R&D knowledge and experience
 |
| **Pathway to 2030 and beyond** | **Monitoring mechanism** |
| Project proposals for scale-up of promising capture technologies that are applicable for power plants and energy intensive industries, in particular the iron, steel, cement and refinery sectors | * Recognition of technologies with the potential for greatest impact.
* Understanding of the pathway to commercialisation.
* Testing centres established for various capture routes.
* Industry expresses an interest in public-private partnerships in order to invest and advance these technologies
 |

## Expected deliverables and timeline

*Developing next-generation capture technologies*

* Execution of larger pilots TRL 6-7 on technologies such as improved solvent and sorbent based systems, various membrane technologies and advances oxyfuel technologies (see Annex ref to add).
* Capture systems with 30 % reduced CAPEX and non-fuel OPEX compared to current state of the art, brought to TRL 6-7 with minimized environmental impact, capture rate at 90 % or more and flexibility with respect to large variability of load changes. A number small-scale capture projects have been identified which may support these outcomes (see Annex ref).
* Development of supercritical CO2 power cycles with oxy-combustion gas turbines, TRL 5-6 [proposed]

## Table 6b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Project/Parties**  | **Implementation Instruments** | **Indicative financing contribution** |
| *Continuation of activities at TCM* |
| Norwegian Government  | Norway Grants 2014-2021  | xxx |
| Air Liquide, Gassnova SF, A/S Norske Shell, Sasol and Statoil ASA, AVR, National Research Councils, and other National funding agencies.  | More information required | More information required |
| *Developing next-generation capture technologies* |
| Industry, both vendors and users; engineering companies; existing and new test facilities and infrastructure networks; research organisations; academia; funding agencies; and governmental CCS bodies. | Industrial fundingState funding | A range of current pilots at TRL6-8 in Europe adapted/retrofitted to a range of new industrial settings and/or boundary conditions (see projects listed in annex)Cost?*Status: Ongoing* |
| As above | Industrial fundingState funding | A range of new pilots built at TRL>6 to demonstrate new capture technologies in suitable industrial environments Cost?*Status: Ongoing* |
|  |  | **Total budget required: xxx** |

## Table 6c: Financing of planned activities to 2030 and beyond

|  |  |  |
| --- | --- | --- |
| **Project/Parties**  | **Implementation Instruments** | **Indicative financing contribution** |
| *Scaling-up of next-generation capture technologies* |
| More information required |  |  |
|  |  | **Total budget required: xxx** |

# R&I Activity 7: CCU Action

Responds to ***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,* and***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*[[10]](#footnote-10)

## Overview of existing and planned activities

CO2 from gaseous industrial effluents is an alternative carbon source for the production of materials, fuels, and chemicals. Previous sustainability assessments have demonstrated that certain CCU technologies may offer a lower carbon footprint than existing production routes, offering a net reduction of CO2 emissions and other potential environmental benefits. Additionally, CCU technologies may also offer potential to contribute to renewable electricity storage and provide low carbon fuels for transport (addressing SET Plan - Action 8).

Many CCU projects have been initiated in Europe with the support of European and Member State funding schemes[[11]](#footnote-11), with a number of these already reaching pilot or demonstration level[[12]](#footnote-12). Further strategic R&I actions are needed to ensure the scaling-up and commercialisation of production activities, improved and new technologies enabling more cost-competitive valorisation of CO2, and longer term disruptive CCU technologies. Detailed assessment of the sustainability and permanence of CO2 abatement for CCU products are needed. Examples of the priority thematic areas are provided below:

*Enabling competitive CO2 valorisation*

Reducing the capital intensity and energy footprint of technologies for the chemical valorisation of CO2 are key elements to make these CCU technologies cost competitive. There are significant costs involved in the capture and purification of CO2. Some CCU options can be developed to use gas streams with lower purification levels than those required for CCS. Research & development is necessary to define the minimum concentration/maximum impurities of CO2 streams that the different conversion processes can tolerate, and develop optimised CO2 capture and purification processes. Research and development is needed for more energy efficient capture and purification technologies and for improved robust catalyst systems, which could cope with less pure CO2 sources, thus improving the overall energy efficiency of CO2 valorisation processes. Modular and containerised approach will also be developed for cost competitive solutions. In addition, a profiling and ranking of different industrial CO2 sources will allow the mapping of large stationary CO2 sources according to different CO2 utilisation paths.

*Carbonation of industrial wastes with CO2*

The carbonation of industrial waste and by-products is proven at commercial scale in specific configurations. This can represent permanent sequestration of CO2 and reduce waste going to landfill and natural resource requirements. Carbonation processes can be applied to a range of industrial mineral wastes and by-products, which are rich in calcium and magnesium silicates and oxides (e.g. fly ash and bottom ash from waste incinerators, cement bypass dust, steel slags) as well as historical deposits of such materials. A range of products can be generated (e.g. aggregates, blends, binding agents, filler loads) for different application markets (e.g. building, roads, plastics, paper, etc.). Waste streams which offer the greatest opportunity to implement carbonation on a large scale in Europe need to be identified, with the aim of developing those with the greatest market value potential and customer acceptance, while not distorting existing markets.

*Production of polymers from CO2*

The chemical valorisation of CO2 into polymers has the potential to significantly reduce the carbon footprint of a range of polymer materials. A number of CO2-to-polymer technologies and variety of new CO2 based polymers, for various applications, could be demonstrated at pilot and small size production scale in the next 5 years.

*Transformation of CO2 into methanol*

Gaseous emissions containing CO2 (and optionally also CO) from various industrial sectors can be converted to methanol through reduction with hydrogen, and used as a chemical building block or as a fuel. Pilot projects are needed to demonstrate that industrial gaseous flows can be integrated to produce methanol in a cost and energy-efficient manner. The major challenges lie in the integration and up-scaling of technologies that are at different TRL levels (from TRL 6 to commercial), the use of intermittent renewable electricity (with validation of the positive impact of stabilizing the power grid) and the development of regulatory incentives that create appropriate market conditions.

*Transformation of CO2 into “renewable” chemicals and fuels*

The integrated process of transforming power, CO2, and water to syngas, then to a variety of fuels or other hydrocarbons is known as “Power-to-X”. This process has been proven on a test plant scale (TRL 6). A fully integrated demonstration scale unit (TRL 7-8) is now required, before progressing to commercial production (TRL 9). Besides total integration, the major challenge for the conversion process are adapting to the intermittent nature of renewable electricity supply in order to produce the right mix of different hydrocarbon products in function of market conditions, and to reduce operational costs. Also required is the development of a digitalised mechanism (e.g. based on the blockchain technology) for monitoring the balance of the centralised production of CO2-derived fuels with the decentralised consumption within the European transportation network. This can establish a virtual accountability link between production and individual consumers, while the physical product stream is distributed through the existing fuel infrastructure.

*Advanced Solar Fuels from CO2*

Breakthrough technologies are required for the direct utilisation of solar energy to producce more efficiently large volume building blocks and energy carriers using CO2 from industrial flue gases as carbon feedstock. High efficient and stable materials and advanced integrated photoelectrocatalytic systems have to be developed for such future efficient CO2 valorisation technologies independant from electricity.

## Identification of gaps

To bridge the gap between lab-scale pilots and pre-commercial pilots (i.e. larger-scale demonstrations) further development will be required for:

* More competitive access to CO2
* More efficient CO2 valorisation process technologies
* Reliable methodologies to assess the sustainability and CO2 abatement potential of CCU products needed support decision making in process design and assessment of products

The potential environmental benefits (including net reduction of CO2 emissions, reduction of the use of natural and fossil resources, valorisation of waste) which may be achieved through CO2 valorisation technologies need to be assessed in order to determine sustainability and the permanence of the CO2 abatement.

## Pathway to 2030

The commercial-readiness of the CCU technologies outlined above varies over a range of TRL levels, from more mature technologies (such as carbonation), to breakthrough innovation technologies (such as advanced solar fuels from CO2). Each will need to be progressed independently to reach commercial scale production, according to the timeframes outlined in the pathway to 2030 monitoring mechanism listed in the table below:

## Table 7a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanisms to 2020** |
| *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 | *Enabling competitive CO2 valorisation* * Proof of concept and development of Improved robust catalyst systems Energy and cost competitive CO2 capture and purification technologies from industrial flue gases
* Improved robust catalyst systems, and energy and cost competitive CO2 capture and purification technologies from industrial flue gases.
* Pilot facilities developed with a modular and containerised approach to allow testing and validation at industrial sites

*Carbonation of industrial wastes with CO2* * At least 4 pilot plants operational

*Transformation of CO2 into methanol* * At least 1 pilot plant (< 10 ktons/year) using intermittent renewable electricity commissioned

*Transformation of CO2 into “renewable” chemicals and fuels (Power-to-X)** At least one pilot operational

*Production of polymers from CO2** At least 2 pilot plants operational
 |
| *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 |  |
| **Pathway to 2030** | **Monitoring mechanisms to 2030** |
| KPIs for 2030? | *Enabling competitive CO2 valorisation* * Potential commercial-scale projects have been identified
* Catalyst systems for CO2 valorisation developed, which are less prone to catalyst poisoning and deactivation, lower cost, and operate at lower temperature and pressure.
* Improved process analytical technology (PAT) development for on-line monitoring of CO2 quality
* Development of modular and containerised pilot facilities at industrial site
* Development of modular skid(s) for industrial testing

*Carbonation of industrial wastes with CO2* * Four pilot plants (10-50 kt/year) operational, ready for commercial scale development.

*Transformation of CO2 into methanol* * At least 1 operational industrial plant producing 50-100 kt/year methanol using one of the different CO2/H2 feedstock configurations.

*Transformation of CO2 into valuable “renewable” low carbon chemicals and fuels* * Production upscaled in 2022 to 10 million litres hydrocarbons per year, with commercial scale production from 2023

*Advanced Solar Fuels from CO2** At least 1 pilot (TRL6)
 |

## Expected deliverables and timeline to 2020

An agreed approach to determine sustainability and CO2 abatement potential will be applied to each deliverable:

*Enabling competitive CO2 valorisation*

* Developed CO2 separation and purification membranes for direct use of flue gases in CO2 conversion processes to chemicals, **2020**

*Carbonation of industrial wastes with CO2*

* Inventory of potential waste streams, potential market size, and assessment of the sustainability and CO2 abatement potential of the products completed, and locations for 4 pilot plants (10-50 kt/year) and priority waste streams identified **2019-2020**.

*Transformation of CO2 into methanol*

* At least 1 pilot scale project at TRL7 (< 10 kt/year) producing methanol from flue gas using intermittent renewable electricity, **2020**.

*Transformation of CO2 into valuable “renewable” low carbon chemicals and fuels*

* Demonstration of an innovative syngas production with > 70% total energy efficiency (power to syngas) and industrialisation from TRL 6 to 9, **2020**
* Demonstration of digital blockchain mechanism which can establish a virtual accountability link between centralized e-Fuel production and individual e-Fuel consumers, **2020**
* Pilot-scale production of syngas (> 1 MW/hour of syngas), and first conversion to hydrocarbon products (500k litres/year), **2020**
* Completed FEED on at least one pilot by **2018**, with pilot plant commissioned by **2020**.

*Production of polymers from CO2*

* At least 2 pilot projects for the production of new or existing polymers based on CO2 produced, with the carbon footprint of the products reduced by at least 15% compared to conventional fossil based products, **2020**.

## Table 7b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Project/Parties**  | **Implementation Instruments** | **Indicative financing contribution** |
| *Enabling competitive CO2 valorisation*  |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding  | See ‘Pathway to 2030’ table below  |
| *Carbonation of industrial wastes and by-products with CO2*  |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding  | See ‘Pathway to 2030’ table below |
| *Transformation of CO2 into methanol* |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding  | Total budget for 1 pilot scale plant (10 ktons/y): € 20 million by 2020 |
| *Transformation of CO2 into valuable renewable chemicals and fuels* |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding  | 1 PilotSee ‘Pathway to 2030’ table below  |
| *Production of polymers from CO2* |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding  | At least 2 pilot projects See ‘Pathway to 2030’ table below |
|  |  | **Total budget required: xxx** |

## Table 7c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Project/Parties**  | **Implementation Instruments** | **Indicative financing contribution** |
| *Enabling competitive CO2 valorisation*  |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding | Total indicative budget of €30-35 million over 5 years (to 2022)  |
| *Carbonation of industrial wastes and by-products with CO2*  |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding | Total cost for 4 pilot plants approximately €10-20 million over 2 years (2021-2022) - depending on the scale and level of flexibility to accept diverse waste streams.  |
| *Transformation of CO2 into valuable renewable chemicals and fuels* |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding | Indicative budget €100 million over 4 year time span until commercial production (in 2021) |
| *Production of polymers from CO2* |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding | At least 2 pilot projects Indicative budget €100 million over 5 year time span (to 2022) |
| *Advanced Solar Fuels from CO2* |
| Industry, Member States, European Commission, with overall coordination at an EU level | Industrial fundingState funding | At least 1 photoelectrocatalytic process pilot with high efficiencies and scalability, including an assesment of sustainabiltiy and CO2 abatement potential Total estimated budget: €40 million to 2025 |
|  |  | **Total budget required: xxx** |

# R&I Activity 8: Understanding and communicating the role of CCS in meeting European and national energy and climate change goals

Responds to ***Target 10:*** *By 2020, Member States having delivered as part of the Energy Union Governance their integrated national energy and climate plans for after 2020, 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*

## Overview of existing and planned activities

*Energy-systems modelling to understand the role of CCS*

Successful deployment of CCS and CCU requires technology and policy to be developed in parallel. Action on technology improvement will reduce the costs related to CCS and CCU, but policies are required to support early deployment of CCS and CCU in Europe. Longer–term, CCS and CCU are expected to be deployed when the cost of emitting CO2 becomes higher than the cost of CCS and CCU. Establishing appropriate policy mechanisms at a European and national level requires an understanding of the potential role of CCS and CCU in the coming decades through advanced energy systems and economic modelling.

One example for such a tool is the JRC-EU-TIMES model, operated by the Joint Research Centre, for assessing long term development pathways for SET-Plan technologies. The JRC-EU-TIMES model is able to capture the interaction between sectors, e.g. transportation and power. 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 CCU has been implemented in the JRC-EU-TIMES model. Methodological improvements of systemic modelling (in particular the interaction of the energy system with related fields) and concrete results for the role of CCS and CCU can be expected to materialise from recently started H2020 projects on modelling transitions pathways such as REEEM[[13]](#footnote-13), SET-NAV[[14]](#footnote-14), REFLEX[[15]](#footnote-15) and MEDEAS[[16]](#footnote-16).

Pan-European analysis should be complemented by regional and national energy system modelling that considers the role of CCS and CCU in the period to 2030 and beyond. In line with the JRC-EU-TIMES model regional and national assessments should focus on all sectors of the economy, consider cross sector synergies and explore the impacts of not deploying CCS and CCU at the national and regional level. This analysis will provide a key input to the development of the integrated national energy and climate plans under the new Energy Union Governance. In the UK analysis is undertaken on the actions and policies that are required to deliver on future carbon budgets under the Climate Change Act. This analysis is underpinned by detailed energy system modelling which highlights the role of different technologies across all energy sectors.

*Understanding and communicating the socio-economic case for investing in CCS and CCU*

Analysis from internationally respected organisations, including the IPCC and International Energy Agency, has identified CCS and CCU as a key technology to deliver on the Paris Agreement. Despite this evidence the value of CCS and CCU is often questioned and not yet integrated into national climate and energy policies. Further research is required into how the socio-economic benefits and the case for investing in CCS and CCU can be conveyed to Governments, key stakeholders and the public.

For example, Sweden is assessing the socio-economic 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-economic dimension. The project provides crucial input to realistic mitigation scenarios and the incentives or disincentives for deployment of BECCS. In the UK, Government and a cluster of energy intensive industries located in Teesside have undertaken a study looking at the creation of a clean industrial development based around a CCS and CCU equipped industrial zone. The goal of the project is retain the regional industrial base, attract new investment and jobs and contribute to meeting the UK’s climate change targets.

*Policy actions to realise socio-economic benefits of CCS and CCU*

Where the analysis above demonstrates the importance of CCS and CCU at the national level then it will be necessary for stakeholders – including European Institutions, national and regional governments and industry – to collaborate in the development and implementation of strategies, roadmaps and action plans that enable the further development and deployment of CCS and CCU in Europe. Taken as a whole the above actions will provide evidence base to support and justify the required investment in CCS and CCU.

## Identified gaps

There is a need for significantly more analysis and understanding of long-term decarbonisation scenarios at the European, regional and national level as relatively few national governments have undertaken the depth modelling work required. The Energy Union Governance arrangements could make a contribution to closing this gap. Activities to understand the socio-economic case for CCS and CCU deployment and the policy actions required to realise CCS and CCU are more fragmented and more significantly more initiatives are needed.

## Pathway to 2030

R&I activity 8 should be considered an ongoing activity that is periodically reviewed and updated in light of increased understanding of the efforts needed to address CO2 emissions and the role of CCS and CCU in industrial, energy and climate policy.

## Table 8a: DOI Targets and Monitoring Mechanisms

|  |  |
| --- | --- |
| **DOI Target** | **Monitoring mechanism** |
| *Target 10:* By 2020, Member States having delivered as part of the Energy Union Governance their integrated national energy and climate plans for after 2020, 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 | *Energy-systems modelling to understand the role of CCS and Understanding and communicating the socio-economic case for investing in CCS and CCU** European countries have completed modelling work to determine the role of CCS and CCU in meeting their national energy and climate change targets.
* Continuation of support for ETIP ZEP under Horizon 2020 Energy work Programme

*Policy actions to realise socio-economic benefits of CCS and CCU** National and European policies which currently support/act as a barrier to CCS and CCU projects have been identified.
 |
| **Pathway to 2030 and Beyond** | **Monitoring mechanism** |
| Policies in place which support the delivery of CCS projects | *Energy-systems modelling to understand the role of CCS and Understanding and communicating the socio-economic case for investing in CCS and CCU** Periodic review and update of National and European energy-systems modelling demonstrating the role of CCS and CCU.

*Policy actions to realise socio-economic benefits of CCS and CCU** Periodic analysis of National and European policies which support/act as a barrier to CCS and CCU projects.
 |

## Expected deliverables and timeline

* Ongoing cooperation with the Dutch government to develop a CCS and CCU Roadmap in collaboration with industry in the Netherlands (oil and gas, power sector, industry) [ongoing]
* Swedish study on the socio-economic prospects for BECCS (P42390-1), timescale of project? [ongoing]
* Further engagement with CCS sand CCU and academic/modelling communities
* Knowledge sharing networks established

## Table 8b: Financing of planned activities to 2020

|  |  |  |
| --- | --- | --- |
| **Project/Parties**  | **Implementation Instruments** | **Indicative financing contribution** |
| *Energy-systems modelling to understand the role of CCS* |
| Member States, European Commission, JRC | Horizon 2020National Research CouncilsState funding | More information required |
| Zero Emission Technology and Innovation Platform | Horizon 2020 | More information required |
| *Understanding and communicating the socio-economic case for investing in CCS and CCU* |
| Zero Emission Technology and Innovation Platform | Horizon 2020 | More information required |
| EERA JP CCS | R&D actions |  |
| *Policy actions to realise socio-economic benefits of CCS and CCU* |
| National Governments and European Commission  | More information required | More information required |
|  |  | **Total budget required: xxx** |

## Table 8c: Financing of planned activities to 2030

|  |  |  |
| --- | --- | --- |
| **Project/Parties**  | **Implementation Instruments** | **Indicative financing contribution** |
| *Energy-systems modelling to understand the role of CCS* |
| Member States, European Commission, JRC, Zero Emission Technology and Innovation Platform | National Research CouncilsState funding | More information required |
| *Understanding and communicating the socio-economic case for investing in CCS and CCU* |
| Zero Emission Technology and Innovation Platform | More information required | More information required |
| EERA JP CCS | R&D actions |  |
| *Policy actions to realise socio-economic benefits of CCS and CCU* |
| National Government and European Commission | More information required | More information required |
|  |  | **Total budget required: xxx** |

# Annex

Spreadsheet containing projects under R&I Activities 5, 6, and 7 attached

1. [SET‐Plan Declaration of Intent on strategic targets in the context of Action 9  'Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)'](https://setis.ec.europa.eu/system/files/integrated_set-plan/setplan_doi_ccus-final.pdf) (European Commission, 2016) [↑](#footnote-ref-1)
2. [Carbon Capture and Storage and the London Protocol](https://www.iea.org/publications/freepublications/publication/CCS_London_Protocol.pdf) (IEA, 2011) [↑](#footnote-ref-2)
3. [SET‐Plan Declaration of Intent on strategic targets in the context of Action 9  'Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)'](https://setis.ec.europa.eu/system/files/integrated_set-plan/setplan_doi_ccus-final.pdf) (European Commission, 2016) [↑](#footnote-ref-3)
4. [SET‐Plan Declaration of Intent on strategic targets in the context of Action 9  'Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)'](https://setis.ec.europa.eu/system/files/integrated_set-plan/setplan_doi_ccus-final.pdf) (European Commission, 2016) [↑](#footnote-ref-4)
5. The Port of Rotterdam is contributing to the project by building an onshore pipeline for transporting the CO2. This work is outside of the scope of the ROAD project and therefore the costs of €15 million are also excluded from the total budget [↑](#footnote-ref-5)
6. [Feasibility assessment of the options for up-scaling proposed CCS facility](http://ccsnetwork.eu/publications/feasibility-assessment-options-scaling-proposed-ccs-facility) (National Grid Carbon, Det Norske Veritas (DNV), 2015) [↑](#footnote-ref-6)
7. [Carbon Capture and Storage and the London Protocol](https://www.iea.org/publications/freepublications/publication/CCS_London_Protocol.pdf) (IEA, 2011) [↑](#footnote-ref-7)
8. <http://www.eurogeosurveys.org/> [↑](#footnote-ref-8)
9. https://pale-blu.com/track-record/track-record-ccus/ [↑](#footnote-ref-9)
10. Important Projects of Common European Interest (IPCEI) are transnational projects of strategic significance for the EU. In 2014 the European Commission adopted specific State aid guidelines for IPCEIs (<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2014.188.01.0004.01.ENG>) allowing Member States to provide financial support to such projects undertaken by industry beyond what is usually possible for R&D and innovation projects. For example, public funding may also support the first industrial deployment of the results of an R&D project and may cover a higher percentage of the funding gap. An example is the IPCEI on High Performance Computing (HPC) and Big Data Enabled Applications launched in January 2016 by Luxembourg, France, Italy and Spain (https://ec.europa.eu/commission/commissioners/2014-2019/oettinger/blog/luxembourg-launches-supercomputing-project\_en). [↑](#footnote-ref-10)
11. Including FP7 and H2020 at European Level, and national programmes such as: "[Technologies for Sustainability and Climate Protection – Chemical Processes and Use of CO2](https://www.fona.de/en/chemical-processes-9852.html)" and “[CO2Net”](http://chemieundco2.de/de/) from BMBF in Germany ; research programs from the British Engineering and Physical Chemistry Research Council; or research programs from ADEME in France. [↑](#footnote-ref-11)
12. Examples include projects by: [Audi E-gas](http://www.audi.ca/ca/web/en/vorsprung-durch-technik/content/2015/10/energy-turnaround-in-the-tank.html), [Covestro](http://www.covestro.com/en/sustainability/carbon-dioxide), [Carbon Recycling International](http://carbonrecycling.is/), [Sunfire](http://www.sunfire.de/en/applications/fuel), [Carbon8](http://www.c8s.co.uk/), [NOAH](http://en.brevik.noah.no/about-noah/research-and-development/), [ORBIX-Recoval](https://www.carbstoneinnovation.be/en/carbstone-innovation-nv-pilot-plant), [CCmResearch](http://www.ccmresearch.co.uk/intro.html) [↑](#footnote-ref-12)
13. http://www.reeem.org/ [↑](#footnote-ref-13)
14. <http://www.set-nav.eu/> [↑](#footnote-ref-14)
15. http://reflex-project.eu/ [↑](#footnote-ref-15)
16. http://medeas.eu [↑](#footnote-ref-16)