CCUS SET-PLAN

Deliverable 2.3

DEVELOP BRIEFING MATERIALS TO CONTRIBUTE TO THE SET-PLAN STEERING GROUP

JANUARY 2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

Project's name: IMPACTS9. IMPACTS9 is a Horizon 2020 project (Coordinated and Support Action) funded by the European Commission for 3 years (from 1 May 2019 until 30 April 2022). Its purpose is to accelerate the progress realised within the CCUS SET-Plan and to support delivery of the R&I activities in the CCUS Implementation Plan.

https://www.ccus-setplan.eu/

Disclaimer

This document reflects only the authors' view and the European Commission and CINEA are not responsible for any use that may be made of the information it contains.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Table of contents

Introduction 3
Input to Clean Energy Transition Partnership – Challenge 1.7 CCUS – Summary 4
Document for SET-Plan Steering Group – The role of CCUS in an Integrated Energy System 7
Input to the SET-Plan Steering Group on market-ready projects 12
Snapshot of CCS/CCU Implementation Working Group 18
Video and background text for the IWG9 snapshot at the SET-Plan conference, 2021 20
CCUS Roadmap to 2030 22

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Introduction

After a brief introduction about the European SET-Plan, the Implementation Working Group 9 (IWG9) on CCUS and the European Green Deal, the briefing materials submitted to the SET-Plan Steering Group are appended.

The SET-Plan

The European Strategic Energy Technology Plan (SET-Plan) aims to accelerate the deployment of low-carbon technologies, improve new technologies and bring down costs by coordinating national research efforts. The SET-Plan brings together EU countries, the European Commission, industries, and research institutions. The SET-Plan defined ten priority areas, covering a wide range of sectors including CCUS, wind, solar, geothermal, renewable heating and cooling, biofuels, etc. The Implementation Working Group 9 (CCUS SET-Plan or IWG9) has been established to help the progress of Research and Innovation (R&I) activities required to achieve the 2020 targets for CCS and CCU agreed by the European Commission, SET-Plan countries, and industry.

The CCUS SET-Plan

The CCUS SET-Plan is composed of 11 SET-Plan countries (Czechia, France, Germany, Hungary, Italy, Norway, The Netherlands, Turkey, Spain, Sweden and the UK), industrial stakeholders, non-governmental organisations, and research institutions. The work is chaired by the Netherlands, Norway, and the Zero Emissions Platform.

Reaching climate neutrality by 2050 will require major efforts from all economic sectors and European society. Higher climate goals mean that all low-carbon technologies under the European Commission's SET-Plan will be crucial in contributing to the transition to a climate neutral economy by 2050 and to accelerate knowledge development as well as technology transfer and up-take. CCS and CCU will play an important role in the delivery of climate neutrality by 2050, enabling a cost-efficient trajectory towards a low-carbon economy with EU's climate objectives.

Develop briefings materials to contribute to the SET-Plan Steering Group

- Input to Clean Energy Transition Partnership
- Document for SET-Plan Steering Group – The role of CCUS in an Integrated Energy System
- Input to the SET-Plan Steering Group on market-ready projects
- Snapshot of CCS/CCU Implementation Working Group
- Video and background text for the IWG9 snapshot at the SET-Plan conference, 2021
- CCUS Roadmap to 2030

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Input to Clean Energy Transition Partnership – Challenge 1.7 CCUS – Summary

Expected outcome

CCUS accounts for 4 Gt CO_2 per year emissions reductions in the energy sector, 1,5 Gt CO_2 per year in the power sector, and 3,5 Gt CO_2 per year in the industry & heavy industry sector in the Sustainable Development Scenario (in total 9 Gt CO_2 per year) relative to the Stated Policies Scenario[1].

To accelerate deployment, framework conditions leading to investments in CO_2 transport and storage infrastructure are required. With the infrastructure in place, European industry will select CO_2-capture to remove CO_2-emissions as a complementary measure to renewable energy and energy efficiency. Several businesses investigate the potential for CDR (Carbon Dioxide Removals) by CO_2-capture from biogenic sources, for example cement plants, waste incineration and bio-refineries.

This 7-year partnership is crucial to set a commercially viable basis for the industrial-scale deployment of CCS and CCU technologies, reducing costs of the technology while raising efficiency and scaling up. R&I activities on CCS and CCU are crucial to achieve climate change mitigation and carbon dioxide removals within this decade, delivering climate benefits for European citizens while, at the same time, safeguarding existing jobs and creating new ones, protecting industrial manufacturing activity and welfare in many EU regions where energy-intensive industries are based.

Undertaking R&I activities on CCS, CCU will be critical to address current challenges on the commercial framework, legal and regulatory issues, technical development of CCS, CCU, and in parallel, to support the EU to become a global leader in low-carbon economy. Creating awareness and involving citizens to make informed decisions is another crucial task for the years ahead.

Identified challenges

Challenges to the large-scale deployment of CCS and CCU technologies still exist, but R&I activities can support the development and large-scale deployment of the technologies in a decisive way.

CH1.7.1 Getting the commercial framework right (see also 13.3.6 and 13.3.7.)

Standardised CO_2 specifications

- Incentives for carbon negative solutions and low-carbon products
- CO_2 stream composition, including technical considerations such as pressure, temperature and physical state and MMV
- Methods for measuring biogenic/fossil CO_2 ratio

[1] 2020 ETP: https://www.iea.org/reports/energy-technology-perspectives-2020#executive-summary

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

- Filling the gaps in databases; CO_2-mixuters' thermophysical properties (density, conductivity, phase equilibria, viscosity, etc)
- Cutting edge technologies for sharing CO_2-mixuters' thermophysical properties and models
- Thermophysical models development based on accurate high-quality experimental data
- CO_2 capture technologies emissions data
- Harmonization of legal standards / regulations relevant for the development of a European CO_2 transport- and storage-network.

CH1.7.2 Accelerating timely deployment at scale of CCS and CCU technologies (see also 13.1, 13.2, 13.3.4, 13.3.5)

- Adaptation of current capture methods to new areas as well as development and deployment of higher TRL capture
- CCU technologies at commercial scale to achieve carbon circularity
- The role of CCS in enabling clean hydrogen
- The role, feasibility and scale of Carbon Dioxide Removals
- Flexible Power Generation
- Projects of Common interest
- Value-chain analyses of CCS and CCU transport systems
- Developing European CO_2 storage by Computational tools in process engineering & intensification (e.g. AI-driven process control and machine learning)

CH1.7.3 Driving costs down – through R&I, learning by doing and economies of scale (see also 13.3.1, 13.3.2)

- High-TRL CO_2 capture technologies (from TRL 5-6 to TRL 7-9), including next generation CO_2 capture technologies including CO_2 capture technologies for industrial clusters and energy applications
- CO_2 transport in pipelines and by ship; models for cost-efficient pipeline design and optimized operation given multiple CO_2 sources and system dynamics. Next generation CO_2 ships design including optimising the transport pressure, and innovative solutions for direct CO_2-injection.
- CO_2 storage including well design, CO_2 behaviour and containment and CO_2 monitoring leading to safe and efficient CO_2 well design and operation.

CH1.7.4 Enabling rapid scale-up to deliver on the climate goals (see also 13.3)

- This refers to the whole array of CCS and CCU research needs.
- CCUS chain development, clusters, cities as incubators, and hubs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

CH1.7.5 Enabling EU citizens to make informed choices regarding the benefits that CCS and CCU bring (see also 13.3.7)

- Harmonised guidelines for life cycle sustainability assessment
- Public awareness and social acceptance of technology solutions towards achieving climate neutrality goals.
- Engaging communities in local projects through development of participatory monitoring programmes.

A link to the full Clean Energy Transition Partnership and SRIA is provided here – link.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Document for SET-Plan Steering Group – The role of CCUS in an Integrated Energy System

The Implementation Working Group 9 (IWG 9) was established within the context of the European Strategic Energy and Technology (SET) Plan to help progress the Research and Innovation (R&I) activities required to achieve the 2020 targets for CCS and CCU agreed by the European Commission, SET-Plan countries, and industry.

The IWG9 is co-chaired by the Netherlands, Norway, and the Zero Emissions Platform. Czechia, Germany, France, Hungary, Italy, Spain, Sweden, Turkey, and the United Kingdom are also represented under action 9 (CCUS) of the SET-Plan.

The IWG9 would like to give the following input regarding the EU Strategy on Energy System Integration.

CO_2 infrastructure, CCS, CCU and hydrogen should be at the core of a truly integrated, climate-neutral energy system.

The European Commission has recently released a Communication on An EU Strategy for Energy System Integration, outlining how a climate-neutral energy system should be developed and what steps Europe needs to take to deliver on this promise. To achieve the EU's objective of becoming climate-neutral by 2050 in a cost-effective way, all low-carbon technologies, such as CCS and CCU, that are scientifically proven and readily available, should be deployed. The strategy for Energy System Integration also takes the view that a technology-neutral approach should be privileged to deliver a net-zero compliant energy system.

Through the strategy for Energy System Integration, the European Commission should especially support projects that will underpin the development of cross-border CO_2 transport, usage and storage infrastructure, thereby supporting projects along the CCS and CCU industrial chain. The strategic development of CO_2 infrastructure is vital to ensure the large-scale decarbonisation of European industrial and energy sectors, while continuing to invest in the scale up of renewable energy sources. CO_2 transport and storage infrastructure is also instrumental in delivering early, large-scale volumes of low-carbon hydrogen produced from reformed natural gas[2] with CCS, which will enable many industrial processes to be redesigned to avoid CO_2 emissions.

There is no doubt that electrification will become an increasingly important feature of future energy systems. Any pathway to climate neutrality by 2050 in the European Union will require a deep electrification of our economy, with renewable energy sources as the primary source of power generation[3]. Large-scale electrification will be a lengthy process that will happen over a considerable period of time. Roughly 20% of the EU's energy demand is met by electricity and 80% by molecules. The reason for this lies in the natural characteristics of molecules, as they have a higher energy density and are easier to transport and store. With

[2] By Steam Methane Reformers and Auto Thermal Reforming
[3] European Commission, A Clean Planet for All, 2018, Shell Sky Scenarios (based on IEA data), A Climate Neutral EU by 2050, 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

a legally binding target of reaching climate neutrality by 2050, electrification alone will not be a viable pathway for energy-intensive industries to decarbonise.

Therefore, complementary methods of decarbonisation must be deployed – such as CCS and CCU – which can provide real emissions reduction and abatement and ensure a cost-efficient transition[4].

When applied to renewable gases, CCS is likely to play a role in a climate-neutral energy system, in particular for the decarbonisation of energy-intensive industries (EIIs). An alternative to the permanent storage of CO_2 is CCU (like the production of synthetic fuels). Synthetic fuels can be associated with very different levels of GHG emissions depending on the origin of CO_2 (fossil, biogenic, or directly captured from the air), and the process used. It is of key importance to properly monitor, report, and account for the emissions and removals of CO_2 associated with the production and use of synthetic fuels to correctly reflect their actual carbon footprint. A robust carbon removal certification mechanism will allow the tracking of the CO_2 fluxes involved in CCU processes. Such certifications can allow regulatory incentives for market take-up of synthetic fuels or other CCU products to be provided, which will be slow due to high investment costs.

CCS and CCU and CO_2 infrastructure can support a low-carbon European economy, safeguarding jobs, industrial activity, and delivering sustainable growth

Reaching climate neutrality by 2050 requires strategic investment decisions, even more so as Europe deals with the aftermath of the COVID-19 health and economic crisis. The pathway towards climate neutrality will bring about a major transformation of energy-intensive industries, such as cement, lime, steel and chemicals, that are at the core of the European economy and provide products that are at the heart of how we live our lives. For these sectors, pathways including CCS and CCU represent the lowest-cost route to decarbonisation whilst maintaining industrial activity[5] and preserving existing jobs. It can capture, reuse and store emissions produced during industrial processes, and it also plays an important role in the manufacturing of clean hydrogen, which can be used to fuel energy-intensive industries and households. An appropriate and thorough GHG emissions accounting is key to ensure that real climate change mitigation is delivered.

When applied to industrial processes and power plants, CCS can secure jobs and incomes and ensure European industrial competitiveness in international markets, while delivering sustainable growth.

Parallel to the storage of CO_2, industry may look into the commercial use of CO_2 for low-carbon products, provided that a thorough life-cycle analysis is conducted. While several CCU applications, in many cases, have a limited potential for CO_2 abatement at scale, they could provide a valuable means of incentivising investment in enhanced CO_2 capture technology in the short term, reducing costs for industry and society.

[4] ZEP report, Climate Solutions for EU Industry, 2017. The report argues that "while electrification can reduce CO_2 emissions in some industries and locations, the abatement potential is limited in sectors where CO_2 emissions are a product of chemical processes and not the combustion of fossil fuels. The amount of electricity required for large scale electrification of Europe's energy-intensive industry would necessitate levels of new low-carbon electricity generation that stretch the concept of feasibility".

[5] Zero Emissions Platform, "Climate Solutions for EU industry", 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

Any CO_2 reduction allocation needs accurate carbon accounting covering all processes involved, including e.g. energy inputs and embedded emissions.

Upon an accurate carbon accounting and life-cycle analysis, these solutions should be combined to enable large-scale permanent storage for captured CO_2 to meet the required level of reductions, thus enabling the long-term sustainability of energy-intensive industries in a low carbon Europe. Given the critical importance of CCS in enabling decarbonisation of Europe's energy-intensive industries, the rapid deployment of CO_2 transport and storage infrastructure to support these important sectors is a matter of priority. A failure to provide such enabling infrastructure in the short term will increase CO_2 liability risk and undermine investments in jobs and economic activity.

CCUS will help both the retention of existing jobs and create new jobs by supporting the gradual yet irreversible decarbonisation of European energy-intensive industries that will be impacted by climate change and the economic crisis. By providing a low-carbon alternative, existing jobs in industries – such as cement, steel, lime, and chemicals – will be preserved. Ultimately, CCUS can enable European industrial regions to remain competitive in a net-zero landscape.

Additionally, the European Union should lay the foundation for a transition towards a climate-neutral economy, incentivising decarbonised industrial products. Coupled with a functional CO_2 price, this should enable the CCS and CCU industry to become self-sustainable in the long term, after the initial support mechanisms that are needed to demonstrate CCS and CCU at a large scale in Europe.

Investing in shared CO_2 transport and storage infrastructure is the **ultimate European project**, and it represents a strategic and instrumental policy decision to preserve Europe's welfare and to make the European society future-proof for a climate-neutral economy. As several CO_2 capture projects are near-ready for large-scale deployment, European CO_2 transport, usage and storage infrastructure would connect CO_2 emitters (industrial hubs and power plants) to storage sites and/or CO_2 off-takers enable the extensive decarbonisation that will be needed to meet the climate neutrality target. Timely development of this infrastructure is crucial and will also enable industry to take a proactive role in the discussions around 2030 and 2050 climate targets.

Europe benefits from privileged conditions. The North Sea basin area is a world-class region for storage. Industrial hubs – such as those around the Ports of Rotterdam, Antwerp, Amsterdam, Le Havre, Dunkerque, and the North Sea Port, as well as the Teesside, Humber, Ruhr, and Cork regions – would be able to capture CO_2 from industrial processes and power plants and use CO_2 transport and storage infrastructure to securely store the CO_2 under the North Sea. Such hubs also profit from the concentrated industrial activity; therefore they might also develop some initial applications of CCU. The next step will be to extend this infrastructure more inland to unlock access to CO_2 storage for industrial areas and power plants that are located further from the coast. Last year's provisional application of amendment 6 of the London Protocol makes it possible

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS

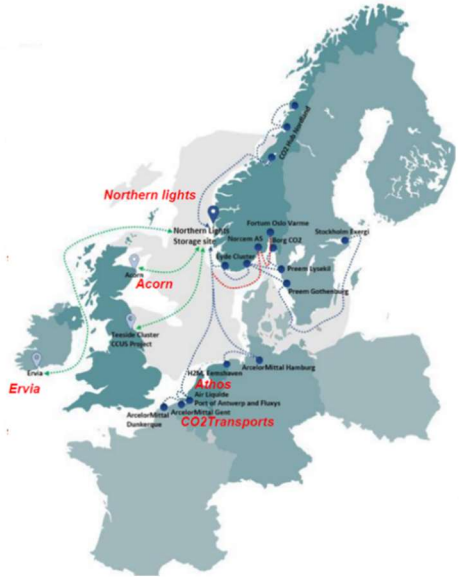
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

to transport CO_2 between countries for the purpose of offshore CO_2 storage. Still it is crucial to formally ratify this amendment.

Securing political support for the five cross-border CO_2 Projects of Common Interest[6] (PCI) is vital, since these projects are on the right track to become operational before 2025. A solid policy framework providing a degree of predictability for long-term investments should be a priority for European policymakers, which brings about the need to revise and extend the scope of existing legislation – such as the TEN-E regulation and EU ETS directive – to prepare for the rollout of CO_2 and clean hydrogen infrastructure. As indicated in the European Taxonomy for Sustainable Finance, all modes of CO_2 transportation to permanent geological storage – pipeline, ship, barge, train, truck – are allowed. This outcome is critical and should be preserved in relevant pieces of legislation, as it will allow near-ready projects to be realised and to create opportunities for numerous CO_2 emitters throughout the entire EU area to have access to low-cost decarbonisation pathways. CO_2 transport for utilisation by pipeline is currently a shortcoming of the European Taxonomy. By allowing a small amount of CO_2 to be transported for utilisation with an initial threshold, the pipeline network should be deemed eligible under the Taxonomy.



A clean hydrogen economy will initially rely on large volumes of clean hydrogen produced from natural gas with CCS, therefore requiring the development of cross-border CO_2 infrastructure[7]. The initial investment in 'blue' hydrogen production and associated infrastructure – linking this clean energy carrier to the customer – will pave the way for the scaling up of green hydrogen, as renewable electricity becomes more abundant.

All efforts to mitigate the impact of climate change must also look at increasing carbon removals from the atmosphere. Carbon removals are needed to address residual emissions to achieve overall net-zero emissions. Given possibilities to connect to the CO_2 transport and storage infrastructure, Europe would have great opportunities to become a global leader on carbon removal solutions.

The work of the Implementation Working Group 9 in the European Strategic Energy Technology Plan (SET-Plan)

Europe is taking a leading role in the fight against climate change and aims at an economy with net-zero greenhouse gas (GHG) emissions by 2050. The adoption of low-carbon technologies at industrial scale is essential to achieve this goal. This is exactly what the European Strategic Energy Technology Plan (SET-Plan)

[6] European Commission, "Technical Information on Projects of Common Interest", 2020
[7] Material Economics, "Industrial Transformation 2050. Pathways to Net-Zero from EU Heavy Industry", 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

aims at realising by bringing together the European Commission and national authorities, as well as industrial, societal and research stakeholders, in a coordinated effort towards climate-neutral energy systems.

Among other priorities within the SET-Plan, **Carbon Capture and Storage and Carbon Capture and Utilisation** is recognised as an essential solution to meet this goal (Priority No. 9). An Implementation Plan laying down specific targets for CCS and CCU deployment and associated R&I priorities for 2020 and 2030 has been developed and the Implementation Working Group (IWG9) has been mandated to follow up the progress. The targets are clustered around five areas: full-scale projects, clusters and infrastructure, capture, storage, and CCU and modelling.

Since 2017, the IWG9 was composed of 11 SET-Plan countries (Czechia, France, Germany, Hungary, Italy, Norway, the Netherlands, Turkey, Spain, Sweden and the UK), industrial stakeholders, non-governmental organisations, and research institutions, and it is chaired by the Netherlands, Norway and the Zero Emissions Platform. IWG9 aims at involving more countries, more funders, and more stakeholders in order to accelerate the large-scale deployment of CCUS technologies and meet the targets of the Implementation Plan.

To assist IWG9 with this work, the IMPACTS9 Consortium – combining the expertise of four partners in the CCS and CCU area – serves as an 'operational arm' for the IWG9. You can find more details on the CCUS SET-Plan at the dedicated website of the projects under www.ccus-setplan.eu. CCS technologies can make a significant contribution to climate change mitigation. Their potential for carbon emissions abatement and removal is scientifically proven and acknowledged by the European Taxonomy for Sustainable Finance[8] and the 'Clean Planet for All' scenario[9]. Commercial, full-chain CCS projects have been operational since the 1980s, with more than 260 million tonnes of CO_2 emissions from human activity captured and stored over 40 years and an overall estimation of around 40 million tonnes of captured and stored CO_2 per year[10] at present. Currently, CCU technologies present different levels of maturity, depending on the final product. Life Cycle Assessments and further scientific evidence describing their climate mitigation potential will be needed to make a case for these technologies.

[8] European Commission, "Taxonomy Report: Technical Annex", 2019
[9] European Commission, "A Clean planet for All", 2018
[10] Global CCS Institute, "2019 Global Status of CCS Report", 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Input to the SET-Plan Steering Group on market-ready projects

This document aims to respond to the SET-Plan Secretariat's request to identify CCS and CCU market-ready projects that are innovative and mature enough and that could be financed through the Recovery and Resilience Fund as well as other sources.

This is a general overview of projects, a living document that will be regularly updated. More and specific information can be found by contacting the projects directly or the companies involved.

Project	Where	What	CO_2 capture/year	Operational	Companies Involved
Technology Centre Mongstad	NO	Post-combustion capture technologies.		Operational	Shell, Equinor, Total
ViennaGreen CO2	AT	Solid sorbent capture technology pilot.		2018	Shell
AVR-Duiven	NL	CO_2 captured from energy-from-waste company and supplied to greenhouse horticulturists	0.1 Mtpa	2019	AVR
LEILAC	BE	Pilot project – cement plan carbon capture.	N/A	2018-2020	HeidelbergCement, Calix
LEILAC 2 project	BE	Pilot installation for breakthrough technology in cement production.	N/A	2020	HeidelbergCement
Fresme	SE	CO_2 captured from the steel industry to produce methanol for the ship transportation sector.	N/A	2020	SSAB, TATA, StenaLine
Fortum Oslo Värme's waste-to-energy plant	NO	Captured CO_2 is converted into a liquid form, transported to a port, and shipped to storage site.	0.4 Mtpa	2020/2021	Fortum

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Norcem	NO	Capture from cement plant.	0.4 Mtpa	2020/2021	HeidelbergCement
Cleanker	IT	Demonstration system in a cement plant of calcium-looping process for CO_2 capture.	N/A	2021	HeidelbergCement, Bucci Unicem
CCU Lighthouse Carboneras			ES	CCU: CO_2 capture through chemical absorption from cement kiln flue gas	0.05 Mtpa
Cheers	China/NO	Demonstration in an operational environment of 2nd generation chemical-looping technology	N/A	2022	Dongfang power group
Northern Lights – EU PCI	NO	CO_2 transport and storage in North Sea Basin. Capture at industrial plants.	1.5 Mtpa (phase 1), 5 Mtpa (phase 2)	2023/2024 (phase 1)	Total, Shell, Equinor
Acorn Sapling – EU PCI	UK	CCS-equipped natural gas processing plant, CO_2 transport and storage in the North Sea.	0.2 Mtpa	2023	Shell, Total, Pale Blue Dot, Chrysaor
Power-to-Methanol Antwerp BV	BE	CCU: Methanol from renewable hydrogen and CO_2 from point sources	0.011 Mtpa	2023, first phase	ENGIE, Fluxys, Indaver, INOVYN, Oiltanking, Port of Antwerp, Vlaamse Milieuholding
North-CCU-Hub	BE	CCU: Methanol from renewable hydrogen and CO_2 from point sources (8,000 tpa of methanol)	0.063 up to 0.305 Mtpa in the final phase	2023	Stad Gent, North Sea Port, UGent (CAPTURE), Bio Base Europe Pilot Plant, Cleantech Flanders, POM Oost-Vlaanderen, ENGIE,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

					ArcelorMittal, Anglo Belgian Corporation, Alco Bio Fuel, Oiltanking, Terranova Solar, Fluxys, Catalisti, Flux50
Westküste100	DE	CCU: Green hydrogen from offshore wind energy combined with CO_2 from cement industry for methanol and aviation fuels. (first phase 30 MW electrolyser)	N/A	2023 first phase	EDF Germany, Holcim Germany, OGE, Ørsted Germany, Raffinerie Heide, Stadtwerke Heide, Thüga and thyssenkrupp Industrial Solutions, Heide development agency, Westküste University of Applied Sciences
H2M - Magnum	NL	Hydrogen from natural gas with CCS for power generation.	Approx. 2 Mtpa	2024	Equinor, Vattenfall, Gasunie, MHPS
Porthos – EU PCI	NL	CCS-equipped industrial cluster, CO_2 transport and storage in the North Sea.	2.5 Mtpa	2024	Port of Rotterdam, EBN, Gasunie Shell, ExxonMobil, Air Liquide
C4U	BE	Demonstration of two highly energy-efficient high-temperature solid-sorbent CO_2 capture technologies for steel industries.	N/A	2024	ArcelorMittal
Onshore storage projects	CZ, RO	Including capture of emissions in cement plants.		2024/2025	HeidelbergCement
3D Project-DMX Demonstration in Dunkirk	FR	CCS-equipped steel-making plant, CO_2 transport and storage in the North Sea.	Approx. 1 Mtpa	2025	Total, IFPEN, ArcelorMittal, Axens, ACP, Brevik Engineering, CMI,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

					DTU, Gassco, RWTH, Uetikon
H-Vision	NL	Production of hydrogen using natural gas and refinery fuel gas.	2.2-4.3 Mtpa	2025-2026	Deltalinqs, Air Liquide, BP, Gasunie, Port of Rotterdam, Power Plant Rotterdam, Shell, Uniper, Royal Vopak, ExxonMobil.
Stockholm Exergi	SE	Bio-based CHP and CCS.		2025	Stockholm Exergi
FLITE	BE	CCU: Sustainable Aviation Fuel (SAF) from ethanol produced from steel-mill off-gases. (44 million litres of SAF using sustainable ethanol as feedstock).	CCU at the Steelanol plant will convert 500 million Nm3/year of carbon-rich industrial off-gases to sustainable ethanol.		
	2025, first phase	LanzaTech BV, LanzaJet ATJ, SkyNRG, Port of Antwerp, Total Raffinaderij Antwerpen, Flanders Investment & Trade, International Airlines Group, ArcelorMittal, Mitsui & Co. LTD, RSB, Airbus, E4tech			
Drax Bioenergy & CCS	UK	Creation of the infrastructure to transform the Humber region into a net zero carbon industrial cluster. Focus on BECCS.	Up to 16 Mtpa	2025-2030	Drax Group, Equinor and National Grid Ventures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

H2H Saltend	UK	Hydrogen from natural gas with CCS (ATR).	0.9-2.6 Mtpa	2026	Equinor
HyDemo	NO	Demonstration of natural gas-based hydrogen production with CO_2 removal and storage for maritime sector.	0.15-0.2 Mtpa (connected to Northern Lights)	2026	Equinor
Norsk e-fuel	NO	CCU: Co-electrolysis of CO_2 (from DAC and point sources) and water with renewable electricity for synthetic liquid hydrocarbons.	0.025 will go up to 0.25 Mtpa	2026	Sunfire GmbH, Climeworks AG, Paul Wurth SA, Valinor
Net-Zero Teesside	UK	CCS-equipped natural gas power plant, CO_2 transport and storage in the North Sea.	5 Mtpa	2026	BP, Shell, Equinor, Total
ERVIA CCUS – EU PCI	IE	CCS-equipped CCGT and refinery, CO_2 transport and storage in Celtic Sea.		2028	Ervia
H2Morrow	DE	Reformed natural gas with CCS for clean steel production.	10.5 Mtpa	2025/2030	Equinor, Thyssenkrupp, OGE
Athos – EU PCI	NL	CCUS network infrastructure with CO_2 capture from a steel plant, transport, reuse or storage in North Sea Basin.	7.5 Mtpa	2027	EBN, Port of Amdsterdam, Gasunie, Tata Steel
Aramis	NL	Conversion of depleted offshore	N/A	Not available	Shell, Total

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

		gas fields into carbon storage sites.			
Missing:					
CCS Ravenna Hub	IT	CO_2 storage in depleted gas fields. Low-carbon hydrogen production. CO_2 captured from bio-refineries.	N/A	Not available	ENI
Greensand	DK				
Magnum	NL				Equinor?
Project	Where	What	CO_2 capture/year	Operational	Companies Involved

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Snapshot of CCS/CCU Implementation Working Group

Exploring the need for CCS, CCU and low-carbon hydrogen to achieve a net-zero GHG emissions in Europe by 2050.

Introduction

The 'Implementing the SET Plan' 2020 report has been published. For CCS and CCU, the input is based on information provided by the whole CCUS community during the summer and this paper highlights this year's most important input.

The IWG9's Implementation Plan (CCUS SET-Plan) work is focused on 10 targets and 8 priority research and innovation activities. Based on the new political landscape – the European Green Deal, the European Climate Law, and the increased 2030 climate target, making CCUS even more crucial in order for Europe to reach its targets in a cost-efficient way – 9 of the 10 CCUS SET-Plan targets have been updated (link) and endorsed by the CCUS SET-Plan Plenary.

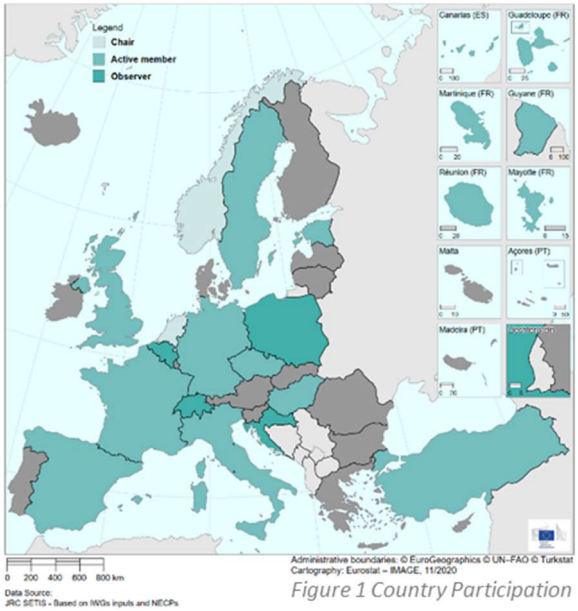


Figure 1 Country Participation

Follow up on current targets

As a basis for the target update, the CCUS SET-Plan prepared a report – 'Follow-up on current targets' (link). While preparing the report, it became evident that some of current targets needed to be updated going forward, given the higher climate ambitions for 2030, and that a number of targets would benefit from an update.

CCUS in future EU decarbonisation scenarios

Another basis for the target update is the modelling exercise, reviewing the role of CCUS in future EU decarbonisation scenarios. The report by the UCL Energy Institute – a part of the CCUS SET-Plan work – has reviewed the role of CCS and CCU in Europe in decarbonisation scenarios consistent with the 1.5°C and 2°C global temperature targets, providing insights on the combinations of technologies that could be compatible with the climate targets under different conditions.

Updated CCUS SET-Plan targets

The updated targets have been communicated to the SET-Plan Secretariat for formal adoption. The CCUS IWG plays a critical role in reaching the European Green Deal climate-neutrality objective by 2050 through

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

the strategic development of CO_2 infrastructure (transport and storage) that will create opportunities for CO_2 emitters across Europe to have access to cost-efficient decarbonisation pathways[11].

R&I activities are structured on five clustered areas: full-scale projects, clusters and infrastructure, capture, storage, and CCU and modelling.

A wide array of projects

81 CCUS projects have been reported to the European Commission, amounting to €646 million (link). 42 % of the projects reported are EU funded, accounting for 53 % of the total reported budget, while 38 % are funded nationally. In addition to these projects, the CCUS SET-Plan also produced a list of European CCUS market-ready projects mature enough that could be financed through the Recovery and Resilience Fund.

Additional activities

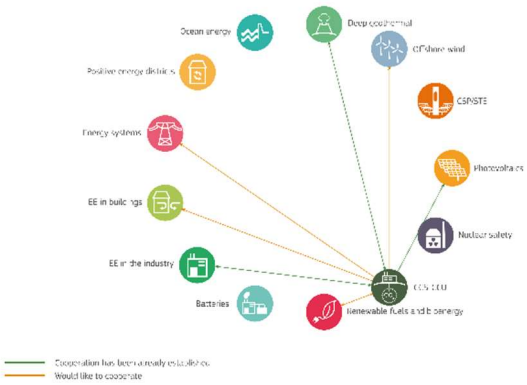
Additional activities highlighted by the CCUS SET-Plan cover several areas, such as:

- The Inclusion of low-carbon hydrogen in targets and activities
- The potential for Carbon Dioxide Removals (CDR) in the targets and activities.
- Enabling further development of CCUS by capitalising on the backbone infrastructure created by the first full-scale project in Norway and the EU ETS Innovation Fund
- The role for CCUS for Europe's integrated energy system
- The inclusion of CCUS in NECPs and member states' long-term climate strategies

Strong cooperation

- ETIP Zero Emissions Platform
- EERA
- Mission Innovation
- CCUS Projects Network
- ERA-NET ACT

Relevant cooperation with other IWGs. These are the IWGs where CCUS SET-Plan can see the most relevant cooperation going forward: Energy Systems, Renewable Fuels and Bioenergy, Photovoltaics and Offshore Wind, Energy Efficiency in Industry and Deep Geothermal.



[11] SET Plan Input Paper "The SET Plan contribution to the Energy System Integration Strategy" https://setis.ec.europa.eu/system/files/energy_system_integration_strategy_set_plan_input_paper_2020.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

Video and background text for the IWG9 snapshot at the SET-Plan conference, 2021

IWG9 has prepared a snapshot video featuring the three IWG9 co-Chairs and representing the success stories of the IWG. The updated targets, as well as the narrative and ongoing work, were also highlighted in the video. The video will be shown during the SET-Plan conference and it is understood that it will not be shared with external partners ahead of it.

Intro to the 'success stories'

There are over 40 'market-ready' projects in Europe – projects that are on track to become operational before 2030 – provided that supportive policy and financial frameworks are in place. You can see many of them later in this presentation – ref. to ZEP website for an extensive overview and categorisation of planned and upcoming CCS and CCU projects in Europe.

The key enabler for these projects is European CO_2 infrastructure, which connects CO_2 emitters in industrial hubs and clusters to safe, geological storage. It is critical that such infrastructure is based on multimodal CO_2 transport and the recognition of CO_2 storage across EU legislation.

CO_2 infrastructure can also enable clean, competitive energy and industrial sectors, early large-scale low-carbon hydrogen, and carbon dioxide removals. The success stories presented were identified on the basis of the 2021 monitoring and reporting exercise – link.

Success stories – Longship, Porthos

Longship, the Norwegian government's full-scale CCS project, is one of the first industrial CCS projects to develop an open access infrastructure with the intent and the capacity to store significant volumes of CO_2 from across the European continent. Longship includes capturing and liquefaction of CO_2 from industrial sources in the Oslo-fjord region (cement and waste-to-energy) and shipping liquid CO_2 from these industrial capture sites to an onshore terminal on the Norwegian west coast. From there, the CO_2 will be transported by pipeline to an offshore storage location subsea in the North Sea, for permanent storage.

The Northern Lights project is responsible for developing and operating CO_2 transport and storage facilities, open to third parties, as part of the Longship project and has PCI status as since the 3rd PCI list. The project is supported by the Norwegian government and private parties – Northern Lights JV, Equinor, Shell, Total, Fortum Oslo Värme and HeidelbergCement.

Porthos is developing a project in which CO_2 from industry in the Port of Rotterdam is transported and stored in depleted gas fields beneath the North Sea. CO_2 will be captured by various industrial companies, compressed, transported through an offshore pipeline to a platform in the North Sea, approximately 20 km off the coast and pumped in depleted gas fields. The depleted gas fields are situated in a sealed reservoir of porous sandstone, more than 3 km beneath the seabed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS
Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

It is expected that, in its early years, the project will be able to store approximately 2.5 million tonnes of CO_2 per year. The possibility for inland connections – from neighbouring countries to the Netherlands – will be evaluated in a second phase. The project has PCI status as since the 3rd PCI list.

Involved parties in this project are the Port of Rotterdam, Shell, ExxonMobil, AirLiquide and Air Products.

Ongoing IWG9 work, a look ahead to 2030: CCUS 2030 Roadmap

Reaching climate neutrality by 2050 requires strategic investment decisions. The pathway towards climate neutrality will bring about a major transformation of energy-intensive industries, such as cement, lime, steel and chemicals, that are at the core of the European economy and provide products that are at the heart of how we live our lives.

For these sectors, pathways including CCS represents the lowest-cost route to decarbonisation whilst maintaining industrial activity[12] and preserving existing jobs. CCS can capture and store emissions from industrial processes, and it plays an important role in the manufacturing of low-carbon hydrogen. Ultimately, CCS can enable European industrial regions to remain competitive in a net-zero landscape. To a more limited extent, and provided that scientific evidence becomes available, CCU will also play a role.

Last year, the IWG9 updated its targets to 2030 to reflect the EU's higher ambition. Based on the higher targets and the EU's commitment to net-zero GHG emissions, the CCUS SET-Plan has developed a Roadmap to 2030, aiming to identify and stress the actions that are needed for large-scale development and deployment of CCS and CCU in Europe during this decade.

With contributions from project developers, academia, industry, and energy companies, the Roadmap outlines policies and R&I needs for CCS and CCU development and deployment, and it identifies barriers and hurdles to overcome in this decade.

[12] Zero Emissions Platform, "Climate Solutions for EU industry", 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CCUS Roadmap to 2030

CCS/CCU technologies are among the low-carbon technologies promoted by the European SET-Plan and recognised as a relevant solution to meet the objective of climate neutrality by 2050. With the European Green Deal and European Climate Law, the EU has increased its climate ambitions and formalised its support for the target of climate neutrality by 2050 and an increased 2030 emissions reduction target of at least 55% compared to 1990 level by 2030 within the EU.

The strongly increased EU ambition for GHG emissions reduction by 2030 will make the role of CCS and CCU even more important. To reach the climate targets in a cost-efficient way, this decade will be crucial: to support early deployment, establish the foundation for CCS and CCU as investible technologies and maturing the technologies at scale.

The CCUS SET-Plan Implementation Plan 2030 targets have been assessed and updated in line with the EU climate targets for 2030 and 2050. The updated targets have been endorsed by the IWG9 Plenary and presented for approval to the SET Plan Steering Group.

Based on the endorsed targets, this CCUS Roadmap 2030 is aimed to give as clear as possible information to the policymakers at EU and MS levels as well as projects, companies, and the finance community on what will be needed to reach these targets.

- The role of CCS and CCU for a just and cost-efficient climate transition – delivering decarbonisation for Europe, safeguarding industrial competitiveness and welfare, creating new jobs while preserving existing ones and delivering climate benefits.
- What will be needed to reach the CCS and CCU targets for 2030 and to set the trajectory towards 2050, referring to policy frameworks, business models, R&D&I needs, enablers and barriers to tackle, etc.
- Showcasing Europe as a global leader on low-carbon technologies and just transition.
- A clear action plan for policy makers.

The CCS/CCU community has been repeatedly engaged in the process. Experts from academia, industry, energy companies, member states have received a draft Roadmap for comments and input in July and have discussed the almost-finalised text at a workshop in October.

Annexes and deliverables will feed into this work and be regularly updated until the end of the grant (April 2022). A link to the full Roadmap is provided here.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842214

+32 2 880 3651 impacts9@ccsassociation.org www.ccus-setplan.eu

CONTACT DETAILS

Carbon Capture & Storage Association
Rue de la Science 14b
B-1040 Brussels
Belgium

CO_2 Value Europe AISBL
Avenue de Tervueren 188A
B-1150 Brussels
Belgium