

SET-PLAN IWG9 CCS and CCU Implementation Plan – Report: Follow-up on targets

Executive summary

Following the announcement of the European Green Deal and the new political landscape of climate neutrality by 2050, the CCUS SET-Plan started the process of reporting on the current targets of the Implementation Plan, set in 2016. As the reporting exercise was carried out, important conclusions emerged.

Firstly, the majority of the targets has been reached or is well in progress to be achieved by 2030. Overall, nine targets remain highly relevant and valid in their formulation. The exercise found that only one target will not be reached in the current formulation. While the areas where the targets have been formulated remain relevant in the 2030 context, it became clear that an increased EU target of 50-55% greenhouse gas emissions reduction by 2030 calls for immediate and substantial action to scale up CCS and CCU technologies within this decade and lay the foundations of CO₂ infrastructure across the EU. To reflect the increased climate ambition of the European Union, the current CCUS targets therefore need to be updated.

R&I activities are important for the deployment of CCUS. Building industrial scale CCS and CCU projects will identify many new challenges that can best be solved by undertaking R&I in parallel with large-scale activities, e.g. increasing the technologies' efficiency and bringing down the costs. Based on the CCUS SET-Plan targets, this report provides an overview on the status of CCS and CCU in Europe, the progress and the reasons for this progress. For each target, the progress so far, the challenges and reasons behind said progress are described, also highlighting a pathway towards 2030. Target 2 and 6 have been met, calling for increased ambition in updated targets. Target 1, 8, 9 will not be reached in their current formulation and will for this reason need to be updated, although their validity remains. For targets 3, 4, 7, 10, reasonable progress has been made towards the achievement of the targets, but updates are still needed. Target 5 remains valid in its current formulation.

In the case of CCS and CCU developments, it is also likely that the next developments will be brought forward by industrial clusters on a regional level, calling for strong cooperation and coordination within European regions and for a clear and supportive pathway from national and European authorities.

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.

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Introduction

Background

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 what the European Strategic Energy and Technology Plan (SET-Plan) 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.

Since 2017, the Implementation Working Group 9 on CCUS (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. The IWG9 is composed of 11 SET-Plan countries¹, 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 to accelerate the large-scale deployment of CCUS technologies and meet the targets of the Implementation Plan.

The IWG9 monitoring and reporting exercise during the autumn 2019 and the results presented in the SET-plan annual report gave an updated picture of the IWG9 progress. Still, there was a need to provide more clarity on the progress of the 10 CCUS SET-Plan targets specifically. To this end, a more thorough follow-up of the progress of the current targets was undertaken.

While carrying out the reporting exercise, it became evident that some of current targets need to be updated going forward, given the higher climate ambitions for 2030. While most targets are still relevant and should be adapted to the climate goals set by the European Green Deal, the report highlights that a number of targets have been achieved and would benefit from an update.

Objective and setup

- This report aims to provide an extended follow-up on the progress of the 10 CCUS SET-Plan targets, giving a clear picture of the status and development of CCS and CCU technologies in Europe that can be communicated to policy-makers and provide an initial background for the discussion on the update of the current CCUS SET-Plan targets.

The report describes the status, relevance and the need for updates, progress and expected development of the 10 targets based on five criteria:

- Description and relevance

¹ IWG9 countries: Czechia, France, Germany, Hungary, Italy, Norway, the Netherlands, Turkey, Spain, Sweden and the UK

- Progress of reaching the target
- Reasons behind the progress
- Pathway to 2030
- Validity of the target

This qualitative description is combined with an extensive overview of ongoing projects along the CCS and CCU value chain. Appended to this report is a list of CCS/CCU projects, highlighting their location, status, timeline for operations, capacities, involved parties, etc. including financing opportunities.

Appended to the report are also the preliminary slides showing the progress for the 10 targets. The slides were presented as preliminary results at the SET-Plan IWG9 plenary meeting in April 2020.

Process

The reporting exercise has engaged a wide number of stakeholders within the European CCUS community. A draft proposal was assembled by the IMPACTS9 Consortium partners, each of which is responsible for the activities of one or multiple targets. Subgroups were also engaged to provide input to the reporting on the current targets and the status of CCS and CCU projects in Europe.

Finally, the document was circulated for comments to a large base of stakeholders ranging from SET-Plan countries to industrial and energy stakeholders, to the NGO community.

The co-chairs have received regular updates on the report at Strategic Coordination Group meetings, which took place in February and July 2020. An update was provided at the Plenary meeting in April 2020, while the final presentation of the report is expected to take place at the SET-Plan IWG9 plenary meeting in October 2020.

In parallel, the IWG9 has also given feedback to the European Commission regarding the SETIS monitoring and reporting exercise, collecting all the developments and progress around CCUS. An Excel sheet collecting all existing and upcoming European R&I projects on CO₂ capture, transport, storage and utilisation has also been provided to the European Commission.

Finally, the IWG9 has also provided input regarding a pipeline of CCS and CCU projects that are considered market-ready and could be financed through the Recovery and Resilience Fund. Input regarding the role of CCUS in an integrated energy system was also submitted to stress the important role of CCUS ahead of this year's SET-Plan conference and for a sustainable economic recovery.

TARGET 1 – Development of CCS and CCU in Europe: CCS in the Power sector

Description and relevance

- *Delivery of a whole chain CCS project operating in the power sector*
- *Pathway to 2030 and beyond: 10 commercial scale CCS projects in the power sector*

The need for early deployment of commercial-scale CCS projects is a key priority for Europe. The increasing global commitment towards climate mitigation targets, the Paris Agreement and the IPCC Global Warming of 1.5 °C report, the renewed interest for CCS in Europe, brought about by the European Green Deal, and the target of net-zero GHG emissions by 2050 make CCS projects crucial for the delivery of a clean, flexible and integrated European power sector.

With the European Taxonomy for Sustainable Finance and the European Investment Bank's new climate strategy and Energy Lending Policy, decreasing the Emissions Performance Standard to 250g CO₂/kWh, unabated gas/fossil fuel energy projects will no longer be financed and an alternative for power generation is needed.

Over the last years, the focus has shifted away from the delivery of whole-chain CCS projects and moved to a structure where capture projects - standalone or clustered - from the power sector or industry are connected to a Europe-wide CO₂ transport and storage infrastructure.

Also, while CCS in the power sector historically has been viewed as a baseload provider, the role of CCS in the power sector has lately evolved towards a means to provide clean, flexible power generation, a well-integrated and readily deployable tool to balance the intermittency of RES sources in the energy system.

Progress

With the withdrawal of the ROAD project, it was clear that this target was not going to be achieved within the 2020 timeframe.

Although there are no commercial scale CCS projects in the power sector, a number of projects are currently under development:

- Capture of CO₂ at the waste-to-energy plant Fortum Oslo Värme in Oslo.
- Ervia CCUS Project, Ireland, includes plans for CO₂ capture on a retrofit on two CCGTs in the Whitegate area of County Cork region.
- Net Zero Teesside Cluster, UK includes plans for CO₂ capture on a new build CCGT (formerly known as the Clean Gas Project – led by OGCI).
- Zero Carbon Humber, UK includes plans for CO₂ capture on biomass power generation at Drax.

- H2M, Netherland, clean hydrogen production in the Netherlands with CO₂ storage in Norway. The hydrogen will be supplied to an existing gas fired power plant which will be converted to use hydrogen as fuel.

Why this progress?

The progress outlined above and the positive developments for CCS in the power sectors, with upcoming commercial CCS projects in the power sector, is an acknowledgement of the great need for CCS to reach the climate targets in certain jurisdictions.

The main reasons behind the failure to meet this target is the lack of support structures for low-carbon firm generation:

- The lack of EU and/or national support schemes that could carry projects in the absence of a functioning price on carbon – *a non-delivering EU ETS system*. As a comparison, the deployment and development of RES was supported with several financing schemes over the years (e.g. the cost of the RES support in Germany, Italy and Spain in 2016 was in the range of 500-600 EUR/ton CO₂ at the same time as the EU ETS price was 5-6 EUR/ton CO₂).
- High political uncertainty.
- Lack of a clear strategy on clean hydrogen. Clean hydrogen production from natural gas reformation and CCS can produce at volume scales of hydrogen, some of which may be used to drive CCGTs and provide a flexible energy generation role in a predominantly renewables dominated grid. However there has been a lack of hydrogen strategy at both a national and EU level.

Even though some of the uncertainties and barriers have been overcome, such as the London Protocol October 2019 resolution on provisional application of cross-border transport of CO₂ for offshore storage, there are still many uncertainties on the timelines for the deployment of CCS and CCU and on the relative role of power CCS, hydrogen and renewable generation in a net-zero energy system at both the member state and EU level.

In addition, when the target was set, the future of coal-fired power plants in those jurisdictions that were developing CCS on power had great uncertainty. The decision to phase out coal (including newer power stations) has cancelled CCS development on coal, but created increased interest in CCS on natural gas, both post combustion and pre-combustion (via clean hydrogen).

Pathway to 2030

There is a new momentum for CCS

The global climate commitment with the Paris Agreement, the IPCC report on Global Warming of 1.5°C and the European Green Deal commitment with the target of net-zero GHG emissions by 2050 set out a clear pathway where commercial-scale CCS is essential.

The European Taxonomy for Sustainable Finance and the EIB's new climate strategy and Energy Lending Policy will also effectively stop further energy projects based on unabated gas/fossil fuel.

The ongoing development, including the five cross-border CO₂ transport and storage infrastructure projects approved as part of the fourth list of projects for common interest, as well as the five proposed CCUS industrial clusters in the UK, make up a good basis for development in light of 2030.

There is an increased interest for CCS in the power sector and especially in combination with biomass (Bio-CCS/BECCS) and waste-to-energy.

How to make it happen

In the absence of a functioning carbon price, several conditions regarding policies and funding opportunities at EU and national levels need to be in place for the deployment and development of commercial-scale CCS projects. There should be a full recognition of the value of clean, firm back-up power to support intermittent RES, i.e. accepted technology for capacity support mechanisms, battery funding policies, strategic infrastructure investment, energy storage technologies, etc.

At the European level, key initiatives to follow are:

- European Climate law.
- Strategy for smart sector integration.
- Horizon Europe, Clean Energy Transition Partnership, etc.
- Innovation Fund, connecting Europe Facility, Just Transition Mechanism, etc.
- EUs taxonomy for sustainable finance.

Different National support mechanisms also exist:

- The UK, Contract for Difference for power CCS– to be confirmed by Government.
- The UK CCUS infrastructure fund (£800m) and explicit support for at least two CCUS clusters to be operational by 2030, including at least one containing power CCS.
- The Norwegian support scheme, CLIMIT.
- The Dutch SDE++ (only for industrial CCS but can cover hydrogen production).
- Etc.

The KPI for 2030 on 10 commercial scale CCS projects in the power sector will also have to be updated.

Is the target valid?

The timeline for the target needs to be updated but the target itself – on early deployment of commercial scale CCS projects – is definitely valid and remains a key priority for Europe. It has been further strengthened by the European Green Deal and the European Climate Law.

TARGET 2 – Development of CCS and CCU in Europe: CCS project linked to an industrial CO₂ source

Description and relevance

- *At least one commercial scale CCS project linked to an industrial CO₂ source, having completed a FEED study*
- *Pathway to 2030 and beyond: 5 commercial-scale CCS projects in the CO₂ emission intensive industries*

The increasing global commitment towards climate mitigation targets – the Paris Agreement and the IPCC Global Warming of 1.5 °C report – and the European Green Deal's target of net-zero GHG emissions by 2050 mark out a clear direction, stressing that industrial decarbonisation is crucial. In Europe, the positive momentum for CCS and CCU has a prominent focus on industrial CO₂ sources. For some energy-intensive industries (often referred to as 'hard-to-abate' sectors), carbon capture is almost the only possibility available for large-scale and cost-efficient decarbonisation.

The need for CCS and clean hydrogen in energy-intensive industries is further strengthened by the introduction of the European Taxonomy for Sustainable Finance, the European Climate Law and the new EIB Energy Lending Policy.

The focus on this development is clearly not on the whole chain CCS projects, but rather on separate and clustered capture projects connected to a separate CO₂ transport and storage infrastructure. The development of European CO₂ transport and storage infrastructure is a crucial basis for deployment of carbon capture in the industry, providing access to secure CO₂ storage for all CO₂ industrial emitters across Europe.

Progress

The target has been reached.

FEED studies for the Northern Lights project (Norway) were finalised in September 2019, including:

- Capture of CO₂ at the Norcem (Heidelberg Group) cement factory in Brevik.
- Capture of CO₂ at a variety of coastal power and industrial facilities in NW Europe.
- The combined transport and storage solution, governed by the collaboration agreement between Equinor, Shell and Total in the Northern Lights Project.

For the Porthos project, Rotterdam, FEED studies are ongoing since December 2019 with the aim to be finalised during 2020:

- Transport to and storage beneath the North Sea is being prepared by Porthos (EBN, Gasunie and the Port of Rotterdam Authority).
- Capture of CO₂ is to take place at refineries and hydrogen producers in Rotterdam: ExxonMobil, Shell, Air Liquide and Air Products.

A number of industrial, CCS projects are also looking at starting FEED studies in 2020/2021. (UK Clusters, ATHOS, Ervia, modular emitters for N.L. e.g. Dunkerque). A more thorough update can be found in the table appended to this report.

Why this progress?

European energy-intensive industries are at the core of EU's decarbonisation efforts. The need for CCUS technology to help making the transition to a climate neutral Europe cost-efficient is evident. This has been clearly highlighted in the European Commission reports² that made up the basis for the EU Industrial Strategy, presented in March 2020.

Also, at the regional and national levels, several pledges for net-zero and emissions reductions have steered industrial efforts towards decarbonisation. For industrial regions this has resulted in a local authority driven ambition for industrial decarbonisation, with several bodies established to start developing CCS capability.

For successful projects, regional ambition is often matched by national support through industrial decarbonisation mechanisms such as the SDE++ (Netherlands), the Norwegian CLIMIT mechanism and a variety of CCS eligible industrial decarbonisation grants in the UK.

Pathway to 2030

It is now crucial to support this positive progress and the further development of these projects and clusters to ensure that they move forward into deployment and operation.

This is a great opportunity to bring forward best practices across other European industrial hubs and clusters. The positive developments highlighted so far will subsequently be the foundations for further industrial decarbonisation, attracting other CO₂ emitters from across Europe and building on the existing CO₂ transport and storage infrastructure.

Industry, especially energy-intensive industry, can play a vital role in delivering on the EU net-zero GHG emissions target by 2050.

The ongoing development on the five cross-border CO₂ transport and storage infrastructure projects, approved in the fourth PCI list (see also target 4), are important steps towards a widespread European CO₂ transport and storage infrastructure. The recent announcement regarding the Longship project and the award of CEF funding to the PORTHOS project, as well as the other PCIs, show the primary role that CO₂ infrastructure development plays in achieving EU's climate objectives.

The development regarding the amendment to the London Protocol, provisionally allowing CO₂ import/export between countries, is a key enabler for cross-country CO₂ transport, but

² Masterplan for a Competitive Transformation of EU Energy-intensive Industries Enabling a Climate-neutral, Circular Economy by 2050 (<https://ec.europa.eu/docsroom/documents/38403>), Strengthening Strategic Value Chains for a future-ready EU Industry (<https://ec.europa.eu/docsroom/documents/37824>)

many other barriers and variables need to be overcome and understood to create positive, further developments.

- A revision of the EU Emissions Trading System, enabling all modalities – other than pipeline – for CO₂ transport. This way, all CO₂ emitters across Europe will be able to connect to safe CO₂ storage and permanently decarbonise their manufacturing. Capture from biogenic CO₂ sources should also be included in the scope of a revised EU ETS.
- Funding opportunities to encourage the deployment and development of all parts of CCS projects, incentivising CO₂ capture at industrial and power plants, supporting the development of CO₂ transport networks and investing in CO₂ storage.
- National CO₂ storage strategies and legislation to enable continuous CO₂ storage appraisal, both offshore and onshore.
- EU and National hydrogen strategies, highlighting the role of CCS for the production of early, large-scale volumes of low-carbon hydrogen from natural gas. This will effectively kickstart a clean hydrogen economy, delivering clean hydrogen to industries and homes.
- Introduction and scope of a Carbon Border Adjustment Mechanism within a functional and extended EU ETS.

All projects mentioned above, as well as others, are preparing to seek financial support under the EU ETS Innovation Fund. Successful applications will increase the chances of these projects passing FID. When operational, CO₂ storage capacity will become concrete and available to other industries. As such, these projects will trigger increased interest to perform FEED studies on CO₂ capture and subsequent transport and storage. Especially for those industries that are geographically further away from (offshore) storage, development of and access to CO₂ transport infrastructure will be crucial (ref. TEN-E regulation).

Is the target valid?

The target is really valid and needs to be updated as well as the timeline. CCUS projects in the energy intensive industry will be crucial in order to reach the EU target of climate neutrality by 2050.

TARGET 3 – Development of CCS and CCU in Europe: CCS clusters

Description and relevance

- *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)*
- *Pathway to 2030 and beyond: 5 commercial-scale CCS projects in the CO₂ emission intensive industries*

This target sets the objective of developing regional CCS and CCU clusters. The target is crucial for the wider development of CCS and CCU in Europe and definitely relevant.

Clustering CCS projects from both the power sector and industrial applications and linking them with CO₂ transport and storage infrastructure (including cross-border, see also target 4) constitutes an essential basis for development of CCS and CCU projects in Europe. This approach will also be vital in order to ensure a geographical spread of CCS and CCU projects across different EU regions. The need for this structure is even more essential now with the European Green Deal and the new ambitious target of net-zero GHG emissions by 2050.

Progress

Reasonable progress has been made towards the achievement of this critical target, as a number of industrial parties have performed feasibility studies from a project development perspective. However, the integration of CCS in the planning towards national decarbonisation plans is less mature and, for example, not at the level as the studies on need for RES (and its consequences for e.g. transmission and distribution capacity).

By 2020, all 5 industrial CCS and CCU clusters (Northern Lights, Porthos, Net-zero Teesside, Le Havre, and Fos-Berre/Marseille) have completed pre-FEED studies and are ready to progress to FEED stage:

Northern Lights project (Norway): FEED studies were finalised in September 2019, including:

- Capture of CO₂ at the waste-to-energy plant Fortum Oslo Värme in Oslo.
- Capture of CO₂ at the Norcem (Heidelberg Group) cement factory in Brevik.
- The combined transport and storage solution, governed by the collaboration agreement between Equinor, Shell and Total in the Northern Lights Project.

The plan is to be operational in 2024.

Porthos project (the Netherlands): FEED studies are ongoing since December 2019 with the aim to be finalised during 2020:

- Transport to and storage beneath the North Sea is being prepared by Porthos (EBN, Gasunie and the Port of Rotterdam Authority).
- Capture of CO₂ is to take place at refineries and hydrogen producers in Rotterdam: ExxonMobil, Shell, Air Liquide and Air Products.

Net Zero Teeside, Le Havre and Fos-Berre/Marseille have all completed pre-feasibility studies and are looking to proceed with FEED studies in 2020.

Additionally, there has been progress developing industrial CCS and CCU clusters into feasibility and FEED stage in other areas, such as Cork, Antwerp, Amsterdam, NW England, South Wales and Dunkerque.

Why this progress?

Recently, the concept of developing industrial CCUS clusters as a mechanism to decarbonise coastal industrial hubs has progressed quite rapidly. This marks a shift away from a single project CCUS value chain with one emitter and one storage site.

Both at an EU, regional and national level, there has been an acknowledgement that using CCUS to decarbonise industrial hubs is a very cost-effective method of decarbonisation and, with regional authority support, many projects have progressed to predicted development timelines.

Pathway to 2030

Many more projects have materialised, which are concentrating on industrial cluster decarbonisation (*table is included below*). It is now crucial that the pipeline of proposed CCUS cluster projects, including the five cross-border CO₂ transport projects on the PCI list, are supported through to full scale operation. Doing so will result in the construction of CO₂ transport and storage infrastructure, which can encourage the development of additional EU wide CO₂ storage projects. For example, CO₂ infrastructure in North-West Europe can encourage CO₂ transport using navigable waterways of the Rhine, Seine, Rhône and Danube, thus connecting many industrial CO₂ emissions through Central and Southern Europe.

The production of blue hydrogen will be an important component of European decarbonisation, as a fuel switching alternative for energy intensive processes, heating and transport. The production of blue hydrogen will rely heavily on the availability of cross-border CO₂ infrastructure and the development of an EU and national hydrogen strategy.

Recent developments such as the amendment to the London Protocol, provisionally allowing CO₂ import/export between countries, is a key enabler but there are many other barriers and variables that need to be overcome and understood for a positive further development. Regarding existing policy and regulatory barriers, a reference to the latter is provided under target 2.

Is the target valid?

This target of developing regional CCS and CCU clusters, is crucial for the wider development of CCS and CCU in Europe and definitely relevant. Both the targets and KPIs must be reviewed in light of the European Green Deal and climate neutrality by 2050 goal. This target also opens up possibilities to include provisions on hydrogen. This will need to be strengthened.

TARGET 4 – Development of CCS and CCU in Europe: Projects of Common Interest

Description and relevance

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

Target 4 assesses the development of European (shared) CO₂ transport infrastructure, eligible for funding as European Projects of Common Interest (PCI). The roll-out of European cross-border CO₂ transport and storage infrastructure is crucial for large-scale decarbonisation of industries and regions, enabling a cost-effective pathway towards decarbonisation.

Large-scale, pan-European CO₂ infrastructure will be required to reach the objective of net-zero greenhouse gas emissions by 2050, therefore the development of such infrastructure should start immediately.

The European Commission has established an instrument to accelerate infrastructure development called Projects of Common Interest (PCI). PCIs can apply for financial support through the Connecting Europe Facility (CEF). In October 2020, the European Commission awarded CEF funding to all 5 PCIs connected to CO₂ networks. Another positive development to note is the decision of the Norwegian government to proceed with the Longship project, the first large-scale industrial CCS project with two capture sites, transport, and underground storage in the North Sea.

Recent developments such as the amendment to the London Protocol, allowing CO₂ import/export between countries, is a key enabler for the development of European CO₂ infrastructure. All CO₂ transportation modalities should also be considered and allowed in EU legislation to develop a large-scale transportation infrastructure. Existing gas pipelines could be repurposed.

Progress

A vote on the PCI list took place during February's European Parliament plenary session. The following cross-border CO₂ projects are included for cross-border carbon dioxide network and will be eligible for funding under the Connect Europe Facility (CEF):

- CO₂-Sapling Project (UK, NL, NO).
- TransPorts (NL, BE).
- Northern Lights project (UK, IE, BE, NL, FR, SE, NO).
- Athos project (NL, IE, DE).
- Ervia Cork (IE).

These projects are all including or connected to offshore CO₂ storage in the North Sea.

More CO₂ transport and storage projects, also covering Southern and Eastern Member States, must be included in the next years' upcoming PCI lists in order to reach the objective of climate neutrality by 2050 and to meet 2030 intermediate targets.

Why this progress?

The strengthened climate ambitions have brought CCS and thus CO₂ transport and storage projects back on the political agenda. Due to the even higher climate ambition, entailed by the goal of net-zero GHG emissions by 2050, there is new momentum for CCS technology and infrastructure.

To support the EU's increased climate ambition, a wide-reaching CO₂ infrastructure will need to be deployed. This will support the decarbonisation of power, industry and other sectors. Cross-border CO₂ transport and storage infrastructure will connect industrial clusters, allowing numerous emitters to benefit from CCS applications. Industrial clusters will also promote the reuse of CO₂ as feedstock at low investment risk and create a reliable supply chain of CO₂ for storage sites.

Storage projects based on ship transport allow for a wider spread and reach for potential supplies of (industrial) CO₂.

Pathway to 2030

To progress in a cost-efficient way towards the objective of climate neutrality by 2050, deployment of CO₂ infrastructure must start immediately. By 2030, the CO₂ projects included in the fourth PCI list should be deployed and operational, paving the way for further possible carbon capture.

More projects will need to be developed to roll out European CO₂ infrastructure. Meeting the targets set out by the European Green Deal will also require an adequate policy framework. Legislative provisions (TEN-E regulation, EU ETS, ESR, etc) and funding measures (CEF, IF) will need to be consistent to the goal of net-zero by 2050, expanding their current scope. The EU taxonomy for sustainable finance gives an indication in this regard. All transportation modalities finalised to storage are listed as sustainable economic activities, therefore qualifying as green investments.

The recent announcement by the European Investment Bank to stop funding unabated fossil fuels from 2021 in combination with the European Green Deal pending TEN-E regulation revision, suggests that a future PCI list will have a significantly different composition. This may result in an increased scope of the PCI list to encourage the development CCS and CCU projects and include provisions for hydrogen infrastructure. In that respect CO₂ storage should also be recognised as an "uneven" spread EU resource that can benefit the EU single market and industry and be included as common interest infrastructure similar to trans-border CO₂ transport.

We would also anticipate more countries joining the London Protocol and stipulating agreements to allow for cross-border CO₂ import/export among countries.

However, there is uncertainty on the eligibility for PCI status for UK based projects as a result of the withdrawal of the UK from the EU. Currently, the Acorn-CO₂ Sapling project is the only UK project listed in the 4th PCI list.

Is the target valid?

Climate neutrality by 2050 will require a cross-border European CO₂ infrastructure. Several projects will need to be developed to deliver on net-zero by 2050. The target is still valid, but the ambition should be increased given the ambition of the European Green Deal.

TARGET 5 – Development of CCS and CCU in Europe: a European CO₂ Storage Atlas

Description and relevance

This target is about creating 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.

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

Target 5, A European CO₂ Storage Atlas, 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.

Progress

Previous EU Framework Programme projects (such as the Joule II (1993-1995); GESTCO (2000-2003); CASTOR (2004-2008) and EU GeoCapacity projects (2006–2008)) have provided a foundation for the Atlas. However, most of these projects utilised confidential data, which has not been possible to publish in the public domain. Although the subsequent CO₂StoP project is considered an important move towards a database with a consistent methodology, the low budget available prevented most countries from gathering new data, providing a complete inventory of potential storage sites and including larger data updates; therefore the resultant database is incomplete and partly obsolete. The understanding of the sites is of low maturity.

Past and current progress for national atlases has been summarised in IWG's Discussion Paper. The *Nordic CO₂ Storage Atlas*, available online³, was produced by NORDICCS – the Nordic CCS Competence Centre in 2011-2015; it covers Denmark, Sweden, Norway and Iceland. The *Norwegian CO₂ storage atlas* was first published in 2011 for the whole Norwegian continental shelf, in 3 separate books for the North Sea area, the Norwegian Sea and the Barents Sea areas which were published in 2019. The *United Kingdom* national database of CO₂ storage information was first populated in 2011 by the UK Storage Appraisal Project. The database is now owned, updated, and developed by the British Geological Survey. It comprises numerical data for more than 550 storage units, including the geological parameters and capacity of the storage units, risk assessment and projections for cost of storage. The *Spanish CO₂ storage atlas* was published as the result of the work done between 2009 and 2010 by Geological Survey of Spain (IGME). The study focuses on the identification of onshore deep saline aquifers with high potential for the CO₂ storage and estimation of storage capacity. The map of the selected structures is completed

³ <https://data.geus.dk/nordiccs/map.xhtml>

and includes description of the regional and local geology, stratigraphic and structural conditions, and seal-storage formation system.

Why this progress?

Developing CO₂ storage is a time-consuming task with exploration, characterisation and development that may take 5 years or more. Open access to information on the locations of potential CO₂ storage sites and the related storage capacity is deemed necessary to swiftly initiate transport and storage infrastructure development in Europe, as has been noted by ZEP (2017). Practical solutions for unlocking confidential information on potential storage sites have to be found so that to avoid unnecessary delays in the development of storage sites is enabled. A storage atlas and related CCS database could fulfil this function, for example by providing generalised information.

A storage atlas will also help in meeting the legal requirement that potential users have transparent and non-discriminatory access to sites for the storage of produced and captured CO₂ (European Commission, 2009: Article 21). A storage atlas will enable comparisons between sites to prioritise them in developing regional or national plans for transport and storage. For the development of individual storage sites the atlas will support project developers and relevant permitting authorities to prioritise the most prospective areas.

Pathway to 2030

The EGDI platform is also the most appropriate mechanism for publishing the new Atlas. There is a concern that providing two different data bases to decision makers will be confusing and the resulting differences in capacity figures will not foster stakeholders' trust in geoscientific capacity assessments.

Is the target valid?

This target is still very valid and does not require updating at this stage. Rather progress must be maintained through funded initiatives, that support collaborative projects to integrate national initiatives and support development in countries that have yet to develop their own atlases.

TARGET 6 – Development of CCS and CCU in Europe: CO₂ Capture

Description and relevance

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 6 addresses the need to progress the capture technology within the field of carbon capture and use/storage (CCUS). There exist several promising technologies, and pilots are needed for these technologies to mature into eventual commercial deployment. There seems to be no "silver bullet", and several pilot technologies should be pursued. To enable the net-zero GHG society laid out in the European Green Deal, carbon negative solutions are needed, as some sources of CO₂ will remain even beyond 2050. Sustainable capture of bio-based carbon emissions has this potential and is therefore a prioritized R&I topic. The target thus addresses both the need for a diverse portfolio of technologies and the need for sustainable carbon negative solutions.

Building industrial scale CCS and CCU projects will generate many new challenges that can best be solved by undertaking R&I in parallel with large-scale activities. An iterative process is needed where R&I projects address specific industrial challenges, with the results then implemented in large-scale projects. A recommended approach would combine existing datasets with specific analyses of industrial areas or plants, obtained by the use of artificial intelligence. Priority research topics include the following macro areas (a more detailed overview in Attachment 1) and are best addressed through R&I at a range of scales from laboratory to pilot scales:

- CO₂ capture in industrial clusters.
- Cost reduction of CO₂ capture.
- Technological elements.

Progress

Given the overview of CO₂ capture technologies, some considerations can be made:

- Large number of existing or forthcoming projects on new capture technologies. However, many technologies are at TRL levels lower than 6-7.
- A few technologies have already been demonstrated in relatively large pilot installations. A few more are expected to be confirmed as demonstrated shortly or will be demonstrated within this year. All in all, it appears that Europe is on route to meet the target of at least 3 pilots on promising new capture technologies.
- At least one technology that is expected to be shortly demonstrated refers to a Bio-CCS application.
- Some additional technologies are expected to be demonstrated in the medium-to-long term.
- The focus of the demonstration projects is mainly on industry sources, in line with the European strategy.

A number of projects potentially relevant for Bio-CCS are linked to the waste-to-energy industry.

Why this progress?

On a high-level the main driver for the progress has been the increasing global commitment towards climate mitigation targets:

- Paris Agreement (and related national pledges)
- IPCC report (and the emission scenarios)
- Renewed interest in Europe for CCUS. Three countries can be clearly identified as the main actors: Norway, UK and The Netherlands.
- Platforms for the share R&D knowledge/experience and for sharing of common infrastructures played an important role in the progress – EERA CCS, ECCSEL, ERA NET, CCUS project network etc.
- Some industrial sectors have led the process of technology demonstration. Hydrogen industry appears to have a clear path ahead due to the identification of a realistic business model. For post-combustion applications the path has been harder due to a more uncertain business model. Cement industry stands out as a very active actor.
- Some barriers that slowed down the progress are related to:
 - Lack of public support for CCS and issues with social acceptance
 - Lack of funding mechanisms for early phase deployment

Pathway to 2030

- A promising overall framework is outlining for the future development of CCUS, with the European Green Deal being a cornerstone of this.
- The mechanisms to encourage and propel sustainable behaviours should be improved and strengthened. The EU emissions trading system (EU ETS) has not worked good enough for industry.
- The difficulty to quickly reach global agreements on mitigation strategies will require countries (e.g., Norway, UK and The Netherlands) and groups of countries (e.g., the EU) to continue show leadership.
- Several new technologies are in development at relatively low TRL levels. Robust funding mechanisms is needed to support the final steps towards industrial size technology demonstrations.
- The development of the capture technologies must be coupled to a parallel development of the other elements of the CCUS chains.
- Further ramping up the number of technologies demonstrated is needed in order to ensure enabling CO₂ capture in several industrial applications.
- Synergies with industrial processes can potentially be exploited and should be investigated.
- Strong focus on Bio-CCS, hydrogen and industrial clusters.

Is the target valid?

The European Green Deal implies a strong need for an increased focus on CCUS in general, in order to be able to reach net-zero by 2050. Other relevant drivers and aspects for this are such as:

- EUs taxonomy for sustainable finance, the
- ETS Innovation Fund
- New industrial strategy for Europe
- European Climate law
- Strategy for smart sector integration
- Clean Energy Partnership

In conclusion, this target is still highly valid, and there is a need to enable more pilots.

TARGET 7 – Development of CCS and CCU in Europe: Storage Appraisal

Description and relevance

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

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

Target 7 addresses the need to progress storage pilots to prepare the way for subsequent larger scale activity. The benefit of a pilot is to demonstrate storage technologies to the public as a safe and effective technology or to appraise the suitability of a storage location. The impact of a series of pilots will be to increase the confidence of all stakeholders in CCS and the associated technologies. The first appraisal steps are likely to start offshore in the North Sea region. In later stages – building on the experience with offshore storage – storage can unfold onshore provided that the local public is supporting the safety and effectiveness of this mitigation technology. In this respect small-scale storage projects can play a crucial role in visualizing the technology to the public.

Progress

A call for proposals for new storage pilots is being published by DG Research in May 2020 which is expected to further support the preliminary appraisal of storage sites.

A study by Pale Blue Dot Energy in 2015 to deliver an open access screened and appraised portfolio of offshore geological CO₂ storage sites. The project involved a detailed appraisal of five CO₂ storage sites, facilities concept design and costing and economics. Potential storage sites are being appraised for industrial CCS in several countries, including the Northern Lights project in Norway, appraisal of depleted gas fields in the Central North Sea for the UK Acorn project, appraisal of potential sites in the Southern North Sea (the Clean Gas project in Teesside UK and Humber (Drax) and North of England projects), the HyNet appraisal of storage in the East Irish Sea, and the Cork CCS project in the Celtic Sea. The ENOS H2020 project is developing a portfolio of onshore storage pilots which will be available by 2020.

Work undertaken within the ACT-funded ALIGN CCUS Project provides a framework for defining the level of understanding of individual sites or how ‘ready’ a site is for operational CO₂ storage (Akhurst et al., 2018). Nine steps for storage site characterisation and the timescale and level of resources needed for a feasible store to become a contingent storage resource are defined. Standardised definitions of these CO₂ Storage Readiness Levels (SRLs) were developed from the experience of storage site characterisation and development in the North Sea.

Why this progress?

New storage appraisals need to be identified and progressed to deliver the actions required under Target 7, supported by existing national and European storage atlases to identify high-ranking locations. The development of the storage appraisals should be actively promoted to find financial support from public and private entities.

Pathway to 2030

In order to achieve the targets set out in the Declaration of Intent KPIs, 15 Permits for storage projects need to have been granted or are in an advanced stage of permitting by 2030. This will require an average of 1-2 sites per year to be appraised to an SRL of 7. A process needs to be put in place by which information from small-scale storage projects may feed back into large-scale storage assessments and the European CO₂ Storage Atlas produced as part of actions under R&I Activity 4 of the Implementation Plan.

Is the target valid?

Storage appraisal remains a very high priority for enabling CCUS in the 2020s. We propose that the original target be updated to reflect:

- The need to develop sufficient storage capacity across Europe for the new Net Zero Targets
- Growing opportunities via PCIs to develop transport and storage networks
- Extending the target beyond 2030 to enable practical storage sites to be developed in a timely manner to enable progress towards 2050 Net Zero target

By 2030, the Declaration of Intent KPIs state that 15 Permits for storage projects will be needed. This was based on an estimate of likely scale to reach commitments in the Paris Agreement (2DS). However a further evaluation to get to Net Zero by 2050 (or thereabouts) is likely to require further increases in the number of storage appraisals after 2030.

TARGET 8 – Development of CCS and CCU in Europe: technologies for the production of fuels

Description

- 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 8 attempts to reflect in one aggregated target the development of different CCU value chains. It reflects sub-targets (i.e. referred to as “deliverables” in the Implementation Plan) from the below thematic areas. All deliverables are to be pursued under the lens of CO₂ emission reduction potential.

- *Enabling competitive CO₂ valorisation:* Cost-competitive membrane separation systems; Robust, cost-competitive catalysts; Containerised modular capture systems; Monitoring systems for CO₂ quality
- *Conversion of CO₂ from flue gases with renewable electricity to methanol:* At least one pilot at TRL 7 (5-10 kiloton/year)
- *Conversion of CO₂ and renewable electricity to other chemicals and fuels:* At least one pilot operational for the production of hydrocarbons (500 kl/y) through syngas
- *Carbonation of industrial waste fractions with CO₂:* Inventory and prioritisation of waste streams; Potential market size of carbonated products; Locations for 4 pilot plants (10-50 kt/y) for different wastes and end-markets.
- *Production of polymers from CO₂:* At least two pilots operational
- *Advanced solar chemicals and fuels from CO₂:* At least one pilot at TRL 6

Relevance

Target 8 was very relevant in the Implementation Plan developed in 2017, as CCU technologies were at the time promising innovative technologies that needed validation at pilot scale (TRL 6-7). The broad character of the target (encompassing different CCU value chains), although rendering reporting at aggregated levels rather challenging, is also relevant as this would ensure that each value chain could be developed in parallel so that CCU technologies can showcase their contribution for GHG emission reduction in different economic sectors (e.g. energy intensive industries, transport, chemical sector, etc.).

Progress and reasoning

At an aggregated level, it is safe to say that Target 8 has been reached. Funding at EU and national level permitted to bring various CCU technologies (including capture) to the stage of pilot validation and often also beyond. Examples of such projects are given below, showing that more than 3 pilots have been developed by 2020.

At the level of the individual thematic areas, not all sub-targets may have been reached. Some of those are not easily measurable (e.g. catalyst development) but in all thematic areas, progress is on-going towards achieving pilot testing by 2022, as some indicative examples below show:

Project	Product	CO ₂ source	Output	Location
MefCO₂, FReSMe (EU)	Methanol	Flue gas	1 t/d	Germany, Sweden
Goerg Olah Plant (IS)	Methanol	Geothermal	4 kt/y	Iceland
Kopernikus P2X (DE)	Fuel	Direct air capture	10 liter/d	Germany
Soletair (FI)	Chemicals	Direct air capture	6 kg/d	Finland
STORE&GO (EU)	Methane	Ethanol plant	1400 m ³ /d	Germany
Jupiter1000 (FR)	Methane	Flue gas	25 m ³ /h	France
ALIGN-CCUS (EU)	DME	Flue gas	50 kg/d	Germany
Audi (DE)	Methane	Biogas	1 kt/y	Germany
Twence	Sodium bicarbonate	Flue gas	8 kt/y	Netherlands

Enabling competitive CO₂ valorisation

- Examples of projects aiming to validate at TRL 6-7 capture systems: [Jupiter1000](#) (FR) and [Méthycentre](#) (FR) using membrane systems to capture CO₂ from flue gases and transform it to methane; EU Projects testing different membrane separation systems across demo sites: [MEMBER](#) (Spain-biomass gasification, Portugal-CHP plant, Norway-steam reforming hydrogen plant); [GENESIS](#) (Switzerland-cement plant, Belgium-steel plant); [MOF4AIR](#) (Turkey-refinery plant, Norway-CHP Plant, France-waste incineration plant); [CARMOF](#) (Greece-cement plant); Further EU projects capture technologies from energy intensive industries like [LEILAC](#), [CEMCAP](#) & [CLEANKER](#) (cement) or [STEPWISE](#) & [Carbon2value](#) (steel)
- Catalyst development for CO₂ conversion processes: Aforementioned projects dealing with catalytic conversion of CO₂ and further projects like: [eCOCO₂](#) (EU) with hybrid catalyst development for direct reduction of CO₂ to jet fuel; [CO₂Fokus](#) (EU) with catalyst development for direct CO₂ conversion into DME and validation at a petrochemical site in Turkey; Entities specialized in catalyst development for CO₂ Conversion like: [Econic Technologies](#), Avantium with [VOLTA](#) technology, the [VOLTACHEM](#) platform, [Harald Topsoe's](#) catalytic technology for CO₂ reduction
- Examples on modular and containerised CCU systems: [Aker Solutions](#) with containerised flue gas capture systems; [Climeworks](#) with modular DAC systems; [Carbon8 Systems](#) for mineralisation; [ICO₂CHEM](#) with Mobile unit for chemical production; [Kopernikus P2X](#) with four stage containerised fuel production; CRI with pilot methanol unit in [ALIGN CCUS](#) project.
- Examples on CO₂ quality monitoring: [Technology Centre Mongstad](#) offering a test bed for different capture systems; Quality monitoring and testing within individual CCU projects combining capture and utilization.

Conversion of CO₂ from flue gases with renewable electricity to methanol: Projects [MefCO₂, FReSMe](#) (EU)

Conversion of CO₂ and renewable electricity to other chemicals and fuels

- [ICO₂CHEM](#) (EU) and the Mobile Synthesis Unit for wax production to be installed in Germany; [BOF2UREA](#) (NL) based on SEWGS capture technology (validated at TRL 6 in Sweden) to achieve urea production of 50kt/y; [Rheticus II \(DE\)](#) from Evonik

and Siemens for the production of specialty chemicals for CO₂ in a test facility starting operation in 2020

- [RECODE](#) (EU) aiming at validation at TRL 6 electrochemical conversion of CO₂ into cement additives; [OCEAN](#) & [CO₂EXIDE](#) (EU) aiming at demonstrating at TRL 6 the production of oxalic acid and ethylene oxide, respectively; [PHECAM](#) (NL) aiming at pilot scale production of formic acid at 50 kt/y scale; [Méthycentre](#) (FR) for the demonstration of synthetic methane production at 50 m³/h scale

Carbonation of industrial waste fractions with CO₂: [FastCarb](#) (FR) and retrofitting of industrial equipment at two cement plants for accelerated carbonation of recycled concrete aggregates aiming at TRL 7 validation; [Carbon8 Systems](#) with its containerised accelerated carbonation technology treating directly flue gases for the production of aggregates; [Orbix](#) with its Carbstone technology for the production of construction materials from CO₂ mineralisation

Production of polymers from CO₂: Project [Carbon4PUR](#) (EU) aiming to validate at TRL 6 the production of polyurethane; Covestro (Germany), Repsol (Spain)

Advanced solar chemicals and fuels from CO₂: Various research teams working on photocatalytic technologies but, to the best of our knowledge, no pilot installation has been development so far in Europe); [Photanol](#) (NL) aiming at production of lactic acid using cyanobacteria as photo biocatalysts at demo scale.

The reasons for not being able to advance pilot and demo validation faster and at wider scale are both generic (applicable to all CCU value chains) and chain-specific (fuels, chemicals, mineralisation products). Some indicative examples:

- Insufficient upstream policy measures (e.g. non recognition of CCU under ETS, Taxonomy) and downstream (e.g. market pull mechanisms in REDII) to foster further deployment at large scale
- The inherent complexity of some CCU technologies and the unavoidable time needed to ascend the TRL scale, combined with low production costs of fossil alternatives
- Non yet extensive quantification of CO₂ emission reduction potential through harmonized sustainability assessment of CCU technologies.
- Scattered and non-systematic support of CCU technology development at national level.

The pathway to 2030

For 2030, the Implementation Plan asks for “*several large-scale commercial plants in place in Europe for each of the main CO₂ valorisation routes, i.e. carbonation, transformation into methanol, fuels and chemicals, and production of polymers*” with following monitoring mechanisms:

- *Competitive CO₂ separation and purification processes*
 - Potential commercial-scale projects identified, Robust, cost-competitive catalysts, Containerised modular capture systems, Monitoring systems for CO₂ quality
- *Conversion of CO₂ from flue gases with renewable electricity to methanol*

- By 2025 at least 1 operational industrial plant producing 50-100 kt/year of methanol using one of the different CO₂/H₂ feedstock configurations, By 2030, several large-scale commercial plants.
- *Conversion of CO₂ and renewable electricity to other chemicals and fuels*
 - Production upscaled in 2022 to 10 million litres of hydrocarbons per year, with commercial scale production from 2023, By 2030, several large-scale commercial plants.
- *Carbonation of industrial waste fractions with CO₂*
 - By 2021, four pilot plants are operational (10-50 kt/year), and by end 2022 ready for commercial scale development. By 2030, several large-scale commercial plants valorising each of the different waste streams demonstrated via the 4 pilot plants.
- *Production of polymers from CO₂*
 - By 2030 at least one large-scale commercial plants.
- *Advanced solar chemicals and fuels from CO₂*
 - Upscaling depending on results of the pilot.

A variety of projects at national and EU scale (some examples mentioned before) are expected to validate pilot or demo operation within the next 2-3 years. Others are on the making as we speak and are looking at a horizon of 2025 and beyond before demo validation (e.g. [Westküste100](#) (DE) in the Heide Refineries complex for the production of jet fuel for the Hamburg Airport within 5 years from 2020; [GreenLab](#) (DK) for a large P2X facility producing hydrogen and methanol after 2022; [Carbon2Chem](#) (DE) for valorisation of steel making off-gases, etc.); North-CCU-Hub (BE) for the production of methanol and further chemicals. And some projects are close to FOAK commercial scale by 2025 (e.g. [Statkraft](#) (NO) for renewable methanol; [Norsk E-fuel](#) (NO) for the production of renewable jet fuel). It is therefore reasonable to believe that these developments will lead to commercialisation of some of the concepts by 2030. Also more advance technologies like solar fuels and chemicals are expected to proceed to considerable upscaling within the next 10 years (see [SUNERGY](#) roadmaps). Horizon Europe will play a crucial role in the TRL 6-7 sphere and within it the SPIRE Roadmap is expected to support upscale of CCU activities. Furthermore, we note that with the Innovation Fund coming to play in the next 10 years to fund some mature and pre-commercial CCU projects (TRL 7-8), this commercialisation timeline could be accelerated.

Is the target valid?

A potential review of the target will reiterate the necessity for pilot validation for those technologies that are still at lower TRL (see thematic area of solar chemicals and fuels). Apart from that, the target should be updated so as to follow the objectives of the *pathway for 2030*. A discussion will still be needed on the exact quantification within the individual priority areas and the appropriate timeframe (i.e. 2030 step and view to 2050 for alignment with Green Deal). If an aggregated target is maintained, it could be in the following lines: at least X commercial scale installations for fuels, chemicals and carbonation products.

TARGET 9 – Development of CCS and CCU in Europe: Important Project of Common European interest

Description and relevance

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.

IPCEI is an instrument that allows Member States to support industrial actors in the development of large-scale transnational projects in ways that would otherwise not be possible due to State Aid regulation. IPCEIs are based on the definition of Strategic Value Chains (SVC), i.e. chains of economic activity of systemic importance for the competitiveness of the EU and with significant potential for growth and job creation. Several SVCs have been defined over the years and IPCEIs are starting to be developed in some of them (e.g. Microelectronics, Batteries). Two SVCs of particular interest for CCU technologies are the ones on “Hydrogen Technologies” and “Low CO₂-emission industries”. CCU projects can be very well included in IPCEIs of those two SVC.

Target 9 is very relevant for the goals of the CCUS SET-Plan because it is a way to promote on the one hand the active and concrete engagement of Member States in CCU deployment and on the other side the collaboration among European industrial players with common interests. It is a way to incentivize transnational collaboration for large scale, mature but not yet cost-competitive projects. While the formulation of the target may need adaptation (see further on validity), the inclusion of CCU projects in relevant IPCEIs is very relevant.

Progress and reasoning

The target as formulated has not been reached, although the formulation needs updating. In any case, the target couldn't have been reached by 2020 because the process for developing the SVC was long and the respective services of the Member States have also first focused on the development of the IPCEI on Batteries during this period. The development of IPCEIs in the two CCU-related SVCs is only now starting to take place. The Hydrogen IPCEI seems more advanced in time. The Low CO₂ emission IPCEI will follow, but no clear timeline is available.

Pathway to 2030

Although nothing is mentioned in the Implementation Plan on the way forward for this target, it is important to maintain it (accurately formulated) because including CCU projects in IPCEIs is a very impactful means to accelerate deployment of CCU technologies at European level CCU technologies. It is reasonable to believe that both CCU-related SVCs will be well developed by 2030 and the IPCEI within them will have been created.

Is the target valid?

As discussed above, the target remains valid as long as its formulation is adapted. We will not be talking about setting up one IPCEI on CCU, rather than including X number of CCU projects in the IPCEI of “Hydrogen Technologies” and the “Low CO₂-emission industries”.

Target 10 – Development of CCS and CCU in Europe: Member States Energy and Climate Plans

Description and relevance

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

Pathway to 2030 and beyond: 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

This target is crucial in order to reach the EU target of climate neutrality by 2050. The target has been further strengthened since the European Commission has proposed to define a clear role for the National Energy and Climate Plans in the newly presented communication of the European Climate Law. A coordinated approach between the EU, regions and the national level regarding targets and strategies for CCS and CCU is critical.

Progress

The European Commission's assessment of the National Energy and Climate Plans has started. However, there are several shortcomings:

- Several Member States did not submit their plans by the deadline of 31 December 2019.
- As the EU 2050 proposed Climate Law was presented in March 2020, many of the plans have not taken into account updated target of net-zero GHG emissions by 2050.
- The 2030 GHG emissions reduction target have yet to be agreed upon by European member states. The European Commission has introduced a proposal backing a target of at least 50% aiming at 55% GHG emissions reduction by 2050, whereas the European Parliament has asked for a 60% target. As discussions and negotiations continue, the European Council meeting in December 2020 should shed more clarity on the final target.

From what can be understood so far, there is an increasing understanding within the Member States regarding the role that CCS and CCU can play in reaching the energy and climate goals. However, the progress is not consistent. Some of the Member States have already included CCS or CCU in their energy and climate strategies (IE, BE, EE, NL, SE + UK, NO), some have highlighted the willingness to join R&D programmes on CCUS (BE, HR, CZ, DE, DK, EE, FR, HU, IE, IT, LI, NL, SE, SK).

Regarding low-carbon hydrogen produced from reformed natural gas with CCS, seven countries plan on going forward with it and include it in the NECPs (CZ, DE, IE, IT, NL, SE, SK + UK, NO).

The expectation is that a clearer picture of how the Member States have included CCS in their strategies and plans will emerge during Q3 2020.

Why this progress?

The status of the progress is, as described above, not easy to determine at this stage. The acceptance of the climate neutrality by 2050 target differ strongly across Europe and all Member States have not yet said yes. Another important reason is that the National Energy and Climate Plans are being updated and finalised against a moving target. The framework of the European Green Deal and the pathway towards 2030 and 2050 is still not clarified and the MFF has not yet been agreed.

Also, the interest and acceptance of CCS and CCU technologies differ remarkably across Europe, where Member States in the north-western corner of Europe – with a direct connection to offshore CO₂ storage in the North Sea – are the drivers in this development.

Pathway to 2030

The European Green Deal with the climate law and the target of net-zero GHG emissions by 2050 sets out a clear direction forward. The NECPs will most probably, as proposed in the EC communication of the climate law, obtain a stronger status and clearer role moving forward towards 2050.

As a part of the European Green Deal, there is a plan to update the NECPs during 2021. It will be crucial to showcase the value of CCS, CCU, hydrogen and European CO₂ transport and storage infrastructure to the Member states that have not yet included CCS in their NECPs.

Apart from relevant assessments of the role of CCS and CCU technologies and strategies including deployment of CCS and CCU, the plans should also include a greater consideration of socio-economic impacts of the deployment of low carbon technologies.

There has been an increase in interest in recent months in CCS and CCU from non-North Sea Basin located countries such as Mediterranean countries, Balkan States and Black Sea countries. It is important that support is given to a pipeline of projects outside of the traditional EU CCS “heartland”. Collaboration, coordination and knowledge sharing will be vital components of CCUS roll-out in across Europe out to 2030 as Member States strive to achieve ambitions outlined in their NECP.

Energy-systems modelling to understand different pathways to reaching net-zero by 2050 and the role that CCS and CCU can play will be very important. The European Commission is preparing new reference scenarios that are supposed to be published in September-October 2020. There is also a study of integrated assessment models highlighting the role of CCS and CCU in long-term decarbonisation scenarios to 2050 as a part of the IWG9 work. This study is planned to be finalised in September 2020.

Is the target valid?

This target is critical.

Projects

Annexed to this report – as [a hyperlink](#) - is a list of existing and upcoming European CCS and CCU projects. The list provides the most up-to-date overview on projects, providing timeline, type of project, location, R&I activity, type of funding, actors involved and, when possible, funding available.

The list has been circulated within the wider CCUS community, reaching out to national governments, research and academia, industries and energy companies, NGOs and all relevant stakeholders.

Conclusions

The report on “Follow-up on current targets” provides an overarching picture on the status of CCS and CCU in Europe. In the context of the European Green Deal, two main conclusions can be drawn from this exercise.

Firstly, the majority of the targets has been reached or is well in progress to be reached by 2030. Only one target will not be reached, due to issues with the formulation, while other targets remain highly relevant and valid in their formulation. As a matter of fact, the majority of the targets remains crucially important for the development, large-scale deployment and commercialisation of CCS and CCU within this decade. Current targets should thus be updated with new formulations to reflect the increased climate ambition of the European Union and the more ambitious goals at a European level.

Target 1 will not be reached in the current formulation. For targets 3 and 4, reasonable progress has been made towards the achievement of the targets, but updates are needed. Target 2 and 6 have been met, calling for increased ambition for the updated targets. Target 5 remains valid in its current formulation. Target 7 remains valid, although an update of its current formulation would be needed. Target 8 and 9 call for an update of their current provision, although their validity remains. Target 10 will need an update; however it remains critical for the European Union and should be monitored.

In the case of CCS and CCU developments, it is also likely that the next developments will be brought on by industrial clusters on a regional level, calling for a strong cooperation within European regions and for a clear and supportive pathway from national and European authorities.

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

Annex 1 - Preliminary slides presented at SET-Plan IWG9 Plenary meeting, 30 April 2020.

DEVELOPMENT OF CCS AND CCU IN EUROPE: CCS IN THE POWER SECTOR – TARGET 1

Delivery of a whole chain CCS project operating in the power sector

Relevance and validity: Very relevant, very valid, needs update and new timeline

- Early deployment of commercial-scale CCS projects is a key priority – CCS is crucial for the European Green Deal, to reach net-zero GHG emissions by 2050 – Sustainable Taxonomy and the EIB's new climate strategy and Energy Lending Policy

- With increasing intermittent RES, CCS in the power sector will also take on a clean balancing role

Progress: Target is not achieved within the set 2020 timeframe – although positive development:

- Fortum Oslo Värme waste-to-energy plant - Norway, Ervia Cork CCUS Project - Ireland, Net Zero Teesside Cluster and Zero Carbon Humber – UK, H2M – Netherlands

- Focus has shifted from whole value chain CCS projects to separate/clustered capture projects, connected to a separate widespread CO₂ transport and storage infrastructure

Why this progress: (1) Lack of EU/national support schemes that could carry projects in the absence of a functioning carbon price, (2) High political uncertainty, (3) Lack of a clear strategy on clean hydrogen

Pathway to 2030: (1) Functioning carbon price, (2) Fully recognising the value of clean firm back-up power to support intermittent RES, (3) Need to update target for 2030



DEVELOPMENT OF CCS AND CCU IN EUROPE: CCS PROJECT LINKED TO AN INDUSTRIAL CO₂ SOURCE – TARGET 2

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

Relevance and validity: Very relevant, very valid, target and timeline need updating

- Early deployment of commercial-scale projects is a key priority and crucial for the decarbonisation of Industry – the need for CCS and blue hydrogen is further strengthened by the Sustainable Taxonomy and the EIB's new climate strategy and Energy Lending Policy
- Deployment of European wide CO₂ transport and storage infrastructure is a crucial basis for deployment of carbon capture in the industry – linking the capture to CO₂ storage

Progress: The target has been reached – Northern Lights project, September 2019

- Many other projects on the way: Porthos project – FEED studies since December 2019, UK Clusters, Athos, Ervia, Antwerp? – looking to initiate FEED studies in 2020/2021

Why this progress: Critical role for CCUS highlighted in EC reports, basis for the EU Industrial Strategy

- Regional climate drive, policy support from governments and investments from private companies – national support mechanisms (e.g. SDE++ in the Netherlands CLIMIT in Norway, CCS eligible industrial decarbonisation grants in the UK)

Pathway to 2030: Crucial to maintain a high level of support and develop shared CO₂ transport and storage infrastructure



DEVELOPMENT OF CCS AND CCU IN EUROPE: CCS CLUSTERS – 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)

Relevance and validity: Crucial – reformulation of target is needed

- Clustering projects from power and industrial applications and linking them to CO₂ storage outlines an essential basis for development of CCS and CCU projects in Europe – crucial to ensure a geographical spread of CCS and CCU projects across Europe

Progress: Reasonable progress towards reaching this target – a number of feasibility studies from a project perspective – however, integration in national decarbonisation planning is less mature

- By 2020, all 5 industrial CCS/U clusters – Northern Lights, Porthos, Net-zero Teesside, Le Havre, and Fos-Berre/Marseille – have completed pre-FEED studies and are ready to progress to FEED stage
- Progress into feasibility/FEED also in: Cork, Antwerp, Amsterdam, NW England, South Wales, Dunkerque

Why this progress: Acknowledgement at EU, regional and national level that using CCUS to decarbonise industrial hubs is very cost-effective

Pathway to 2030: Many more projects have materialised – crucial that the pipeline of proposed CCUS cluster projects are supported through to full scale operation



DEVELOPMENT OF CCS AND CCU IN EUROPE: PROJECTS OF COMMON INTEREST – 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

Relevance and validity: Crucial – new target needed

- Pan-European CO₂ infrastructure will be needed to reach the objective of net-zero emissions by 2050 – therefore the development of such infrastructure should start immediately
- All CO₂ transport modalities should be considered – existing pipelines can be repurposed

Progress: Target reached – 5 CO₂ projects are included on the PCI list, will be eligible for CEF funding: CO₂-Sapling Project (UK, NL, NO), TransPorts (NL, BE), Northern Lights project (UK, IE, BE, NL, FR, SE, NO), Athos project (NL, IE, DE), Eria Cork (IE)

Why this progress: Due to the even higher climate ambition, entailed by the goal of net-zero GHG emissions by 2050, there is new momentum for CCS technology and infrastructure

Pathway to 2030: Policy and funding support will be needed throughout the decade to ensure that a CO₂ transport and storage infrastructure is largely deployed by 2030

CO₂ transport and storage projects also covering Southern and Eastern EU must be included in the next years' PCI lists



DEVELOPMENT OF CCS AND CCU IN EUROPE: A EUROPEAN CO₂ STORAGE ATLAS – 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

Description: A European CO₂ Storage Atlas will prioritise prospective areas and will enable the development of transport infrastructure to be optimised

Relevance: An online resource of prospective storage sites is needed to facilitate site comparison, site ranking, and integrated planning of storage and transport development.

Progress: IWG9 Storage Subgroup have written a paper, presented at IWG9 Plenary in October 2019, on specifications and next steps for Atlas development. National Atlases are being developed in some countries. CO₂Stop Database published by JRC.

Why this progress: Storage development can take several years and an open-access Atlas will support faster development. It will also support third party access.

Pathway to 2030: The EGD platform may be a suitable mechanism for publication. Dedicated funding to enable integration, update and standardisation of national atlases.

Target validity: Still valid.

www.ccus-setplan.eu



DEVELOPMENT OF CCS AND CCU IN EUROPE: CO₂ CAPTURE – 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

Description: Target 6 supports the progress of the capture technology within the field of CCUS.

Relevance: Target 6 addresses both the need for a diverse portfolio of technologies (there is no "silver bullet") and the need for sustainable carbon negative solutions

Progress: A few technologies already demonstrated, a few more will be demonstrated within this year. One technology to be shortly demonstrated refers to a Bio-CCS application

Why this progress: On a high-level the main driver has been the increasing global commitment. On a national level the engagement from industry, its cooperation with a strong R&D sector and the presence of offshore storage capacity. The barriers have been the lack of business models, of public support and of funding mechanisms for early phase deployment

Pathway to 2030: A promising overall framework is outlining (European Green Deal). Several low TRL technologies in development that need robust funding mechanisms. Need to ramp up the number of technologies demonstrated, strong focus on Bio-CCS, hydrogen and industrial clusters.

Target validity: The European Green Deal implies a strong need for an increased focus on CCUS in general, in order to be able to reach net-zero by 2050. So - this target is still highly valid, and there is a need to enable more pilots.



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DEVELOPMENT OF CCS AND CCU IN EUROPE: STORAGE APPRAISAL – TARGET 7

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

Description: Storage pilots are needed to prepare for subsequent larger scale activity

Relevance: Pilots can demonstrate safe and effective storage technologies and/or appraise new storage locations – this will increase stakeholder confidence

Progress: New storage pilots expected to be funded via H2020 call in May 2020 to support the preliminary appraisal of storage sites – Several research and industrial projects in NW Europe undertaking storage appraisal in support of pilots (e.g. Northern Lights, ACORN, Clean Gas Project, Humber, HyNet, Cork CCS, ALIGN...). More needed in other regions

Why this progress: New storage appraisals to deliver the actions required under Target 7 to meet future storage requirements from a growing CO₂ capture network

Pathway to 2030: To meet Declaration of Intent KPIs, 15 storage permits are needed by 2030, i.e. 1-2 sites per year to be appraised to an SRL of 7

Target validity: Storage appraisal remains a very high priority for enabling CCUS in the 2020s – Target should be updated to reflect CCUS role in achieving Net Zero – Likely to require more and faster appraisal



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DEVELOPMENT OF CCS AND CCU IN EUROPE: PILOTS ON CCU – 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

Description: Aggregated target encompassing technologies for fuels, chemicals and materials (separated into thematic areas with more specific sub-targets). Aggregation necessary to keep thematic areas running at parallel.

Relevance: Highly relevant due to the need for pilot validation of CCU emerging (at the time) technologies

Progress: The target in its aggregated form is **achieved** (see projects MefCO₂, FreSME, Kopernikus P2X, STORE&GO, Jupiter1000, ALIGN-CCUS, etc.). Sub-targets are not all achieved but progress is on-going

Why this progress: EU and national funding has allowed to arrive at pilot scale (TRL5-6) for some technologies. Slower achievement at disaggregated level is a combination of reasons (inherent process complexity & time for up-scaling, upstream & downstream policy support, symbiotic infrastructure, attractiveness of business plan, extensive quantification of mitigation potential,...)

Pathway to 2030: Reaching commercial scale facilities for technologies demonstrated at pilot/demo scale. Reaching pilot validation for lower TRL technologies

Target validity: In principle remains valid but quantification should reflect progress done



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DEVELOPMENT OF CCS AND CCU IN EUROPE: IPCEI FOR CCU – 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.

Description: Member States (MS) supporting large scale transnational projects beyond State Aid regulations. Based on Strategic Value Chain (SVC) "Hydrogen Technologies" and "Low CO₂-emission industries".

Relevance: Highly relevant for engagement of MS and collaboration among large industrial players

Progress: Target not achieved as such, but also wrongly formulated. No IPCEI on CCU can be set up as CCU is not a SVC. Inclusion of CCU in the above mentioned IPCEI is realistic. IPCEIs on hydrogen are on the making (e.g. expression of interest)

Why this progress: No IPCEI on CCU can be set up as CCU is not a SVC. Inclusion of CCU in the above mentioned IPCEIs is realistic. IPCEIs on hydrogen are on the making (e.g. expression of interest).

Pathway to 2030 : Include CCU projects in the IPCEI(s) of hydrogen and low CO₂ industries

Target validity: Target remains valid for 2030 but needs to be formulated correctly



DEVELOPMENT OF CCS AND CCU IN EUROPE: MEMBER STATES ENERGY AND CLIMATE PLANS – 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

Relevance and validity: Very relevant – need to update target and timeline

- This target is crucial and has been further strengthened since the EC has proposed to define a clear role for the NECPs in the European Climate Law – a coordinated approach between the EU, regions and the national level regarding targets and strategies for CCS and CCU is critical

Progress: Awaiting final NECPs, EC assessment and a further update of the plans

- Increasing understanding of the important role of CCS/U – some MS have already included in their strategies (IE, UK, NO, Flanders, EE, CRO, CZ, FRA), some have highlighted CCS as a possibility (SK, IT, BE, DE, GR)

Why this progress: Better understanding of the role of CCS/U in reaching climate goals

Pathway to 2030: To be determined once NECPs and assessment completed

- Most probably more important role for NECPs
- Energy-systems modelling on pathways to net-zero by 2050 and the role of CCS/U will be important

