Zero emissions platform

CO_2 Capture and Use (CCU)

The potential to reduce CO_2 emissions *and* accelerate CCS deployment in Europe

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European Technology Platform for Zero Emission Fossil Fuel Power Plants

Key conclusions

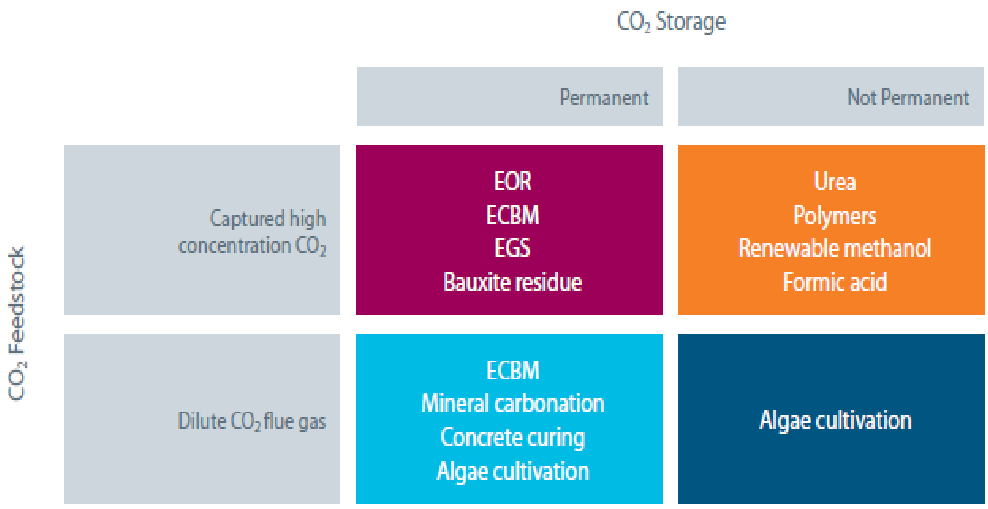
- The use of captured CO_2 as a product (CO_2 Capture and Use, or CCU) could be an alternative to – or linked to – the permanent storage of CO_2 in geological formations.
- **CCU technologies which lead to a net reduction in CO_2 emissions should be the main focus**, i.e. they ultimately result in products that either show almost no decay over the long term, or result in permanent geological storage, e.g. Enhanced Oil/Gas Recovery (EOR/EGR), Enhanced Coal-Bed Methane (ECBM) and mineral carbonation.
- **CCU could add significant economic value to a CCS project** and accelerate deployment – even if there is only temporary 'storage' of CO_2.
- **The greatest potential for CCU in Europe is offshore EOR (mainly in the North Sea) and in Eastern Europe** which has mature fields with historically low recovery-rates. Annual incremental North Sea oil production in economically viable CO_2-EOR/EGR projects could reach 180 million barrels[4] – with the simultaneous storage of 60 million tonnes of CO_2.
- **Urgent action is needed to exploit the full potential of CCU to reduce CO_2 emissions and accelerate CCS deployment:**
  - Develop likely CCUS scenarios for Europe (including on-/offshore CO_2-EOR/EGR and CO_2 mineral storage) via the European Industrial Initiative on CCS.
  - Include CCU and CCUS in Horizon 2020 as an enabling technology for CCS in Europe.
  - Develop business models for successful CCUS in Europe.
  - Design tailor-made incentive schemes at national and EU level to kick-start early CO_2-EOR/EGR and CO_2 mineral storage projects.

What is CO_2 Capture and Use (CCU)?

The use of captured CO_2 as a product (CO_2 Capture and Use, or CCU) could be an alternative to – or linked to – the permanent storage of CO_2 in geological formations. However, from a climate protection perspective, **CCU technologies which lead to a net reduction in CO_2 emissions should be the main focus**, i.e. they ultimately result in products that either show almost no decay over the long term, or result in permanent geological storage (CO_2 Capture Use and Storage, or CCUS). Mineral carbonation is an example of a natural process that already permanently 'stores' CO_2.

CCU can also reduce emissions by substituting production methods with alternative, lower-emitting CO_2 technologies, e.g. feeding greenhouses with captured CO_2 from power plants instead of burning additional natural gas. However, CCU technologies which result in non-permanent products that are later converted back to CO_2 after usage or due to decay within a few decades, may be interesting from an industrial production perspective, but are not relevant for climate protection. Nevertheless, some may act as an enabler or supporter of CCS, thereby having an indirect positive effect, e.g. by strengthening the business case for CCS by creating a product – and additional revenues – using a partial CO_2-stream.

The Global CCS Institute (GCCSI) has indentified some CCU technologies in analogue categories:



As CCUS has the highest potential to reduce CO_2 emissions, this paper therefore focuses on these technologies, together with those that have the potential to facilitate the deployment of CCS.

CCU must include permanent CO_2 storage to qualify as a climate mitigation technology

In order for CCU to qualify as a climate mitigation technology, there must be a long-term storage component. Enhanced Oil/Gas Recovery (EOR/EGR), Enhanced Coal-Bed Methane (ECBM) and mineral carbonation are all technologies that can lead to the permanent storage of CO_2. However, in mining activities (e.g. fracking, or as an extraction fluid for oil shales and other unconventional hydrocarbons), the use of CO_2 is more concerned with facilitating extraction than permanent storage.

Methods for the tertiary production of oil remaining after primary and secondary recovery are commonly termed EOR. Two such methods – miscible and immiscible flooding – partly or fully rely on CO_2 injection. Secondary recovery is based on water injection, but CO_2 injection could be promoted as the secondary recovery mechanism.

EOR is by far the most advanced CCUS technology, with decades of experience leading to large-scale economical operations. In contrast to CCS business models, industrial EOR projects have proven to be economical in cases of cheap CO_2 sourcing. With rising oil prices and by combining both business models, EOR-CCS becomes more attractive and may serve as an important enabler for large-scale CCS. Conservative assumptions estimate an increasing global demand for CO_2 for EOR of at least 5%/a, reaching values of 118 Mt CO_2 /a (SBS Energy Institute) to 255 Mt CO_2 per annum.[1]

Depleted gas fields also offer significant storage potential. However, increasing and prolonging the tail-end operation of a field via EGR is more strongly limited to specific geological conditions, compared to EOR and only a few projects exist, e.g. the K12-B offshore operation in the Netherlands. EOR, as well as EGR, leave a considerable share of the CO_2 behind in the reservoir, but not necessarily the entire injected volume. Depending on the geological conditions and operation, the hydrocarbon extraction is accompanied by CO_2 release, which may not be accounted as stored. Monitoring and accounting in accordance with EU Emissions Trading Scheme (ETS) regulations is therefore key.

Mineral storage is another technology that may be termed CCUS and could, for some industries, be more relevant than storage in the subsurface. Metal oxides (especially alkaline oxides such as CaO and MgO) can react with CO_2 to build stable carbonates that may be easily stored or used as materials, mainly in civil engineering. This technological chain leads to a high mass flow with sourcing and logistics challenges in the supply of oxides – while producing a product that may be suitable for the mass market. Alternatively, products of industrial processes (e.g. water purification, ashes) that are already produced at the CO_2 emission site, may offer mineralisation capacities to bind at least a fraction of the CO_2 stream.

CCU could add significant economic value to a CCS project

CCU with only interim fixation of CO_2 cannot be seen as CO_2 abatement – as the UNFCCC[2] has clearly stated. However, adding economic value to a CCS project via a CO_2-based product generation could facilitate investments in CCS.

CO_2 can be transferred to many different products via chemical, biochemical, photochemical or electrochemical reactions (DNV 2011). These products may then be used as either feedstock for value added (bio-)chemicals (e.g. organic and inorganic carbonates, polymers, urea etc.), or as a medium for intermediate energy storage (e.g. methane, syngas).

Bound in CO_2, carbon is in its lowest energetic state for ambient/surface conditions and any transfer is therefore energy demanding. This plays a role in the economic evaluation, but must also be considered in the energy/CO_2 balance of the entire CCU chain. The development of energy-efficient processes, use of excess power, use of renewables (e.g. solar to grow algae) and the advancement of catalysts are therefore of special interest for CCU.

Methanisation and other intermediate energy storages may play an important role in emissions reduction, even if individual projects are neither CO_2 abating nor economically feasible as stand-alone projects. However, by offering energy storage capacities for surpluses generated in electricity, they enable the integration of a higher share of renewables in today's energy market, thereby reducing the CO_2 emissions of the total energy supply system. Their deployment may also benefit from being built upon an existing infrastructure to transport, store and distribute the products.

CCU should be fully represented in Horizon 2020

ZEP recommends that the following technical gaps, barriers and topics for further R&D are addressed in the Horizon 2020[3] roadmap:

- Analyse the market potential of individual CCU technologies.
- Analyse the mitigation potential of CCUS technologies.
- Undertake lifecycle assessments/CO_2 balance for CCU technologies.

[1] International Energy Agency (IEA)
[2] United Nations Framework Convention on Climate Change
[3] http://ec.europa.eu/research/horizon2020/index_en.cfm

- Promote the development of CO_2-based (mass) products to enable commercialisation.
- Integrate CO_2-based energy storage in power-to-gas(-to-power) concepts, including R&D on intermediate or dynamic CO_2 storage.
- Reduce the costs of refurbishing oil/gas installations for CO_2-EOR.
- Develop smart and flexible offshore solutions to additional equipment requirements, e.g. floating equipment for conditioning, offloading and re-capture of CO_2.
- Establish consistent business models for combining CO_2-EOR with CO_2 storage and the re-use and storage of a combined stream of CO_2 from multiple sources.
- Develop a CO_2 supply system for the step-wise development of CCUS, from pilot- to large-scale EOR/EGR, comprising multiple sources and sinks (both petroleum and buffer aquifer reservoirs).
- Combine EOR/EGR with optimised, dedicated long-term storage.
- Develop a flexible design for the CO_2-hub, enabling adjustments to local conditions (especially complex for the transport of liquid CO_2 by ship).
- Assess operational risks and challenges specific to offshore EOR.

Creating a business case for EOR/EGR with CO_2 storage

In the case of CO_2-EOR with long-term storage, there are two different drivers (increased oil and CO_2 storage), requiring two different business models. In all the 70+ CO_2-EOR projects in North America, only the 'increased oil' driver is active, with any CO_2 storage incidental (even if the CO_2 had been anthropogenic, which, in most cases, it is not). The use of captured CO_2 for EOR therefore unlocks value via increased oil production, but the entire value chain must be in place in order to achieve it. The JRC[4] has estimated that annual incremental North Sea oil production in economically viable CO_2-EOR/EGR projects could reach 180 million barrels – with the simultaneous storage of 60 million tonnes of CO_2.

From an EOR point of view, CO_2 is therefore a valuable commodity which should be used sparingly, with 'losses' in the reservoir kept at a minimum. CO_2 is returned to the surface with the additional produced oil and, after capture, recycled back to the oil recovery activity. Losses in the reservoir depend on local conditions, but generally amount to between 1/3 and 1/5 of the total injected CO_2.

Over time, increasing amounts of oil containing CO_2 is produced and the need to add CO_2 to the flooding activity decreases correspondingly. For such a CCU project to become a CCUS project, another business plan for maximising CO_2 storage is required – driven not by increased oil production, but storage credits. Each link in the chain therefore has to make sufficient return on its investment in order have an incentive to start and continue the process, and work on the business case should focus on potential early movers.

A key driver is the availability of a suitable oil field for EOR which is affected by factors such as the:

- Maturity of the field, which provides a potential window of opportunity
- Technical suitability of the field
- Strategy of the field owner.

The business case for EGR has the same basic structure as for EOR. However, the revenue per tonne of injected CO_2 (on the upstream side) is significantly less as less gas remains from conventional production; the value of the same volume of gas gained per tonne CO_2 is less than for oil; the share of injected CO_2 emerging in hydrocarbon production increases more quickly and early breakthroughs are more likely.

[4] E. Tzimas, A. Georgakaki, C. Garcia Cortes and S.D. Peteves (2005). Enhanced oil recovery using carbon dioxide in the European energy system, European Commission, Joint Research Centre (JRC), December 2005, Report EUR 21895 EN.

The urgent need for incentives to kick-start CCU projects in Europe

The case for CCS incentives to drive deployment is very clear and will not be further discussed here.[5] However, the case for onshore CO_2-EOR is not as straightforward, as illustrated by the many projects in the U.S. which were initially set in motion by tax breaks for EOR and not specifically directed at CO_2.

In Europe, the greatest potential for CO_2-EOR is offshore (mainly in the North Sea) and in Eastern Europe which has mature fields with historically low recovery-rates. Given the costs of offshore EOR, incentives are essential. However, it is critical that they are tailor-made and not confused with incentives for CCS, which could potentially undermine the climate mitigation case and create public mistrust. A similar line of argument would be valid for mineral carbonation storage (and potentially EGR).

Key recommendations

- Develop likely CCUS scenarios for Europe (including on-/offshore CO_2-EOR/EGR and CO_2 mineral storage) via the European Industrial Initiative on CCS.
- Include CCU and CCUS in Horizon 2020 as an enabling technology for CCS in Europe.
- ZEP to provide recommendations regarding business requirements for successful CCUS in Europe.
- Design tailor-made incentive schemes at national and EU level to kick-start early CO_2-EOR/EGR and CO_2 mineral storage projects (e.g. contributing to the development of a logistics structures).
- Urgently resolve transboundary transport, liability and storage credit allocation issues.

The Zero Emissions Platform (ZEP)

Founded in 2005, the Zero Emissions Platform (ZEP) is focused on CCS as a critical technology for achieving Europe's energy, climate and societal goals. A coalition of over 200 members from 19 countries – representing academics, scientists, European utilities, petroleum companies, equipment suppliers and environmental NGOs – ZEP serves as an advisor to the European Commission on the research, demonstration and deployment of CCS.

www.zeroemissionsplatform.eu

[5] See ZEP's response to the European Commission's consultative Communication on CCS: www.zeroemissionsplatform.eu/library/publication/223-zepresponseccssomm.html.