Fact sheet

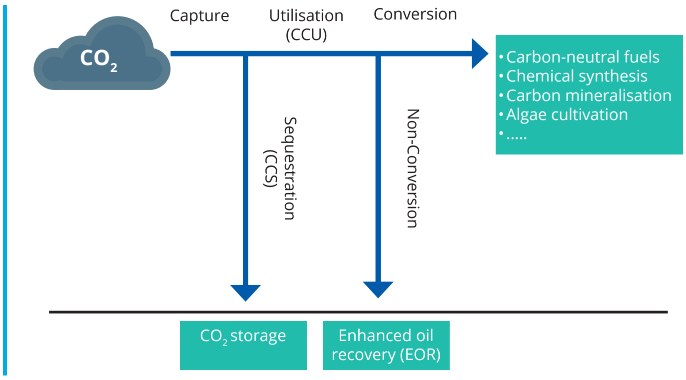
Carbon capture and use and storage (CCUS)

The transition to a low carbon world requires a transformation in the way we manufacture iron and steel. There is no single solution to CO_2 free steelmaking, and a broad portfolio of technological options is required, to be deployed alone, or in combination as local circumstances permit. This series of fact sheets describes and explores the status of a number of key technologies and issues.

What is CCUS?

As is the case of carbon capture and storage (CCS), CCUS technologies separate and capture the CO_2 generated during the iron and steelmaking process. The difference is that using CCS, the CO_2 is stored permanently underground.

The CO_2 can be chemically converted into other products such as plastics, concrete or biofuel, or used in enhanced oil recovery (EOR).



Why consider CCUS?

CCUS technologies can add significant strategic value in the transition to net-zero[1]:

- CCUS can be retrofitted to existing power and industrial plants, which could otherwise still emit 8 billion tonnes (Gt) of CO_2 by 2050.
- CCUS can tackle emissions in sectors where other technology options are limited, such as in the production of cement, iron and steel or chemicals, and to produce synthetic fuels for long-distance transport (notably aviation).
- CCUS is an enabler of least-cost low-carbon hydrogen production.
- CCUS can remove CO_2 from the atmosphere by combining it with bioenergy or direct air capture to balance emissions that are unavoidable or technically difficult to abate.

CCUS now

Globally, some 230 million tonnes (Mt) of CO_2 are used every year.[2] The largest consumer is the fertiliser industry, where 130 Mt CO_2 is used in urea manufacturing, followed by oil and gas, with a consumption of 70 to 80 Mt CO_2 for EOR.

In EOR, CO_2 is injected into mature oil fields in their final phase of extraction.

Of the 33 large scale CCS projects currently in operation, CO_2 from 22 of them is used in EOR operations[3], which represents over 80% of the CO_2 captured in large scale facilities.

While it may seem unintuitive that extracting extra oil using CO_2 can lead to climate benefit, a large proportion of the CO_2 injected into oil fields for EOR purposes (around 90 - 95 %) is permanently sequestered, trapped in the geologic formation where the oil was once trapped.

Other commercial applications include food and beverage production, metal fabrication, cooling, fire suppression and stimulating plant growth in greenhouses. Most commercial applications today involve direct use of CO_2.

CCUS in the steel industry now

Enhanced oil recovery (EOR)

CO_2 captured from the Emirates Steel plant, located in Abu Dhabi, UAE, is currently being used in EOR operations Annually up to 800kt of CO_2 is captured and injected into the Abu Dhabi National Oil Company's oil reservoirs.

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Chemical production

- LanzaTech piloted a plant looking at converting steel plant waste gases to ethanol at New Zealand Steel in 2008.[4] The process has subsequently been commercialised, with the first plant beginning operation in 2018 in China at Shougang Steel. The plant produced 30 million litres of ethanol for sale in the first year of operation.[5,6] A large scale plant at ArcelorMittal in Ghent, Belgium began operation in 2022. Once production reaches full capacity, the Steelanol plant will produce 80 million litres of advanced ethanol, almost half of the total current advanced ethanol demand for fuel mixing in Belgium.[7] Ethanol can be used in a wide range of applications, including the production of synthetic fuels.[8]
- thyssenkrupp's Carbon2Chem project is looking to produce ammonia and methanol from steel off-gases and reached a pilot phase in 2018. The company is aiming to develop an industrial scale plant by 2025.[9]
- The Carbon4PUR, project by a consortium of 11 partners across Europe, including ArcelorMittal, is piloting converting steel off-gases to polyurethane foams and coatings (20 t/yr).[10]
- The FReSMe project, a consortium of European partners including Tata Steel and SSAB, is piloting steel off-gas conversion to methanol (1 t/day).

Challenges and opportunities

Permanent carbon reduction potential

In many cases, CCUS products, such as synthetic fuels, are combusted and the carbon contained within them is released to the atmosphere as CO_2. Some stakeholders argue that these applications merely delay the release of CO_2 unless a corresponding reduction in fossil-based emissions occurs.[11]

At the same time, wider use of CCUS syn-fuels would reduce the need to extract natural resources from potentially fragile ecosystems and reduce the need to transport large quantities of fossil fuels, with the associated emissions and environmental risks.

It is possible to use synthetic fuels as a medium to store the output of variable renewables (for example, the Sunfire Project) if CCUS based synthetic fuels are combined with direct air capture technology (DAC).

It will be important to ensure that carbon accounting rules applied to the entire CCUS system are credible and take a life cycle approach to accurately assess the positive and negative impacts of CCUS technology.

Other CCUS applications

Applications other than synthetic fuels are being considered; these include oxygenated compounds (polycarbonate, urethane, etc.), biomass-derived chemicals, commodity chemicals (olefin, BTX, etc.), minerals such as concrete products, concrete structures, carbonate, etc.[12]

Scale and impact

Achieving emission reductions commensurate with the IEA's Net Zero Scenario will require global emissions to fall by over 30Gt per year. It seems unlikely that CCUS applications on their own will be capable of making a material impact.

However, growth in CCUS will enable the further development of CO_2 capture technology and the deployment of CO_2 transportation infrastructure. Many steel plants are located in industrial clusters in close proximity to other emitters, and a shared CO_2 transport and storage infrastructure that many industries can use could be an efficient and cost-effective way to meet climate targets. The IEAs note that 'deployment strategies that shift the focus from large, stand-alone CCUS facilities to the development of industrial "hubs" with shared CO_2 transport and storage infrastructure are also opening up new investment opportunities.'[13]

It is also possible to transition EOR facilities into CCS facilities, which have the potential to permanently sequester significant and material amounts of CO_2.[14]

Inert nature of CO_2

CO_2 is an inert gas and converting it into any useful chemical or fuel will require energy to be used.

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1 A new era for CCUS – CCUS in Clean Energy Transitions – Analysis | IEA
2 Putting CO2 to Use – Analysis - IEA
3 A new era for CCUS – CCUS in Clean Energy Transitions – Analysis | IEA
4 LanzaTech strikes deal with NZSteel to extend project | NZ Herald
5 World First Products made from Recycled Pollution Reduce 7 Emissions and Keep Carbon in the Ground! | LanzaTech
6 World's First Commercial Waste Gas to Ethanol Plant Starts Up | LanzaTech
7 ArcelorMittal inaugurates flagship carbon capture and utilisation project at its steel plant in Ghent, Belgium | ArcelorMittal
8 Virgin Atlantic and LanzaTech Celebrate as Revolutionary Sustainable Fuel Project Takes Flight | LanzaTech
9 Climate strategy Steel | thyssenkrupp Steel
10 Carbon4PUR
11 BellonaBrief: CCU in the EU ETS: risk of CO_2 laundering preventing a permanent CO_2 solution | Bellona.org
12 Roadmap for Carbon Recycling Technologies Formulated (meti.go.jp)
13 A new era for CCUS – CCUS in Clean Energy Transitions – Analysis | IEA
14 Insights Series 2015 - Storing CO2 through Enhanced Oil Recovery – Analysis | IEA