

CARBON CAPTURE AND STORAGE: A CRUCIAL PIECE OF THE PUZZLE IN INDUSTRIES' PATH TO NET-ZERO

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Nearly all climate change modelling scenarios highlight that CO₂ capture, transport and storage play an important role in reaching climate neutrality at both the EU and global levels.¹² With several [CCS projects under implementation](#), and legislative initiatives underway such as the [Net-Zero Industry Act](#) introducing a first-of-its-kind CO₂ injection capacity target placing unprecedented responsibility on oil and gas producers, and the European Commission's upcoming Communication on the CCUS Strategy through the [CCUS Forum](#) Bellona Europa finds it important to highlight in this explainer what CCS is and how it should be best used to help reach our climate targets.ⁱ

CCS is not a silver bullet solution. The technologies' contribution lies in their ability to effectively reduce emissionsⁱⁱ in heavy industries generally considered "harder-to-abate" because of their so-called process emissions.ⁱⁱⁱ In these cases, reducing emissions is technologically very difficult, or impossible, by means other than CCS. With targeted use, CCS has a pivotal role to play in Europe's green and just transitions and ensures that these economically important and largely welfare-carrying sectors can be part of a net-zero world. More in the long term, CO₂ transport and storage infrastructure networks will be essential to deliver negative emissions, without which we will not be able to reach our climate goals.

CCS: A KEY TECHNOLOGY FOR INDUSTRIAL DECARBONISATION

Sectors such as steel, cement, chemicals, and waste incineration all require a variety of different technologies to fully decarbonise their production processes. While several sources of emissions, for instance, those related to energy use, can be eliminated through direct electrification, increased energy efficiency or switching to the best available technologies (BATs), persisting CO₂ emissions like those resulting from chemical processes (i.e., process emissions) are left to be dealt with using CCS technologies.

8% CEMENT

Cement Production is responsible for 8% of global CO₂ emissions.³ While it is important that industries improve the energy efficiency of their technologies with BATs (such as reducing the clinker-to-cement ratio), certain process emissions will require CCS for full abatement.⁴ In a cement plant with modern technology and equipment, the production of 1 tonne of cement results in approximately 0.59 tonnes of CO₂⁵, of which approximately 60% if the result of the calcination process.⁶

7% STEEL

Steel production is responsible for 7% of the global CO₂ emissions^{iv}, including process emissions with the EU being the second largest steel producer in the world.⁷ Producing 1 tonne of steel results in 1.5-1.9 tonnes of CO₂ emissions⁸ increasing energy efficiency and using BATs can decrease to fully decarbonise steelmaking⁹. This is where CCS technologies come into play,¹⁰ at least in the foreseeable future (around the early 2040s).

2.5% CHEMICALS

Direct CO₂ emissions from the chemical industry claimed 2.5% of global CO₂ emissions (2019).¹¹ Europe is the second largest chemicals producer in the world.¹² A quarter of the CO₂ emissions are a result of chemical reactions inherent to production.¹³ CO₂ is also emitted during the production of ammonia, which is used for fertilisers or purifying water supplies.¹⁴

CO₂ is typically emitted during the production of ammonia, which is used for fertilizers, purifying water supplies, cleaning products, and as a refrigerant, and used in the production of many materials, including plastics, pesticides, and textiles.¹⁵



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ⁱ While the terms "net zero" and "climate neutral" are similar in meaning, "net zero" is more narrowly focused on the balance of GHG emissions emitted and removed, while "climate neutral" takes a broader view of reducing emissions and achieving a state where no net GHG are emitted into the atmosphere.

ⁱⁱ Emission reductions realised through CCS refer to the technologies' ability to capture CO₂ before it reaches the atmosphere and permanently store it away from the atmosphere.

ⁱⁱⁱ Some energy use is hard to electrify (though maybe not impossible) and in some cases processes can be changed without electrification or by indirect electrification (e.g., via green hydrogen).

^{iv} Covers energy use related emissions, fuel combustion emission, emissions from industrial processes and also fugitive emissions, but does not cover AFOLU sources.

BREAKING BARRIERS TO SCALE UP CCS

CCS is necessary for its ability to deliver in the fight against climate change and to reach net-zero by 2050, yet there are several challenges and barriers standing in the way of its deployment at scale.

The EU has set a target to become climate-neutral by 2050, which includes reducing emissions from industry incentivised primarily by the [EU Emission Trading System](#). To achieve this goal, the EU is on its way to establishing a comprehensive policy framework for Carbon Capture and Storage, relying on the 2009 [CO₂ Storage Directive](#), which sets out the legal framework for safe CO₂ storage activities in the EU, and the Innovation Fund, which provides financial support for CCS among other renewable and low-carbon technologies.

The EU's [Net-Zero Industry Act](#), currently under review by the co-legislators, aims to scale up the manufacturing of clean technologies in the EU (such as CCS) to accelerate efforts to reach net-zero emissions by 2050. Aiming to attract investments and facilitate market access for renewable and low-carbon technologies is indispensable for the transition. Crucially, the Act introduces a first-of-its-kind CO₂ injection capacity target setting unprecedented responsibility on oil

and gas producers, thereby reducing investment risks for every stage of the CCS value chain.

The [CCUS Forum](#) brings together CCS stakeholders (policymakers, industry representatives, and NGOs) from across Europe to exchange knowledge and ideas, share best practices, and work together to address challenges in the deployment of CCS projects. To create an enabling policy and investment environment for CCS deployment and accelerate the implementation of CCS projects in Europe the Commission organised several Working Groups. Through this work, stakeholders support the Commission in developing its Communication on the CCUS Strategy, which will be published at the end of 2023.

The EU and a number of its Member States are taking active steps to promote the development and deployment of CCS as part of their efforts to achieve net-zero emissions. Policies and initiatives vary between countries but share the common goal of supporting the transition to a low-carbon economy and reducing emissions.

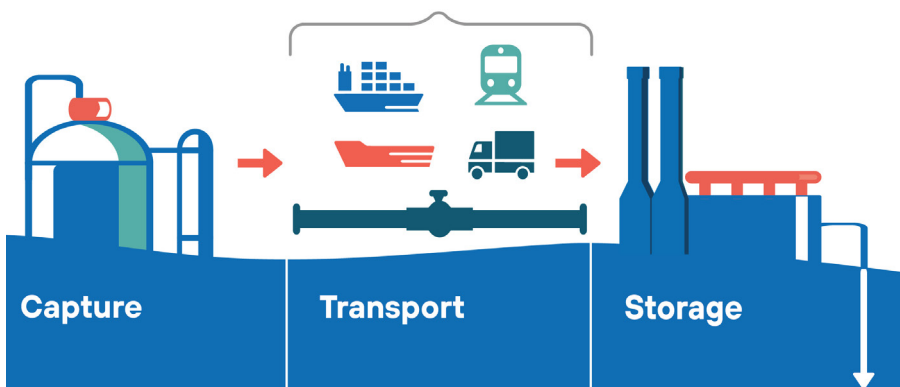
THE CCS PARADOX

The main challenges faced by CCS are related to its value chain's reliance on capital intensive infrastructure developments. CCS is a group of technologies associated with three activities in one value chain: CO₂ capture, transport, and storage. Each of these activities can be conducted using a range of technologies characterised by various maturity levels, costs, and applicability. The purpose of CCS is to prevent CO₂ from entering the atmosphere where it contributes to global warming and by extension climate change.

One of the greatest challenges facing the CCS value chain currently is the "chicken and egg" problem, also known as the CCS paradox. The close interconnection of the three parts of the value chain to be developed and deployed by different actors creates uncertainties thereby imposing high risks for investment for the entire value chain. The issue lies in the channelling of investment towards the development of

CO₂ storage capacity, for which a reliable supply of captured CO₂ would be necessary as an incentive. At the same time, to boost investment in the capture of CO₂ it is necessary to have the insurance of knowing that storage sites are under development and will be ready to transport and store CO₂ once available.

To realise its potential in reaching net-zero by 2050, a European CCS infrastructure network and market requires public support mechanisms. Given its substantial contribution to emission reductions, it must be treated as a public good to enable first movers and the development of a market. Its successful deployment also hinges on a harmonised regulatory framework and a clear European strategy to ensure coordinated development and efforts.



CCS essentially constitutes a group of technologies aimed at reducing carbon dioxide emissions from primarily industrial processes by capturing CO₂, transporting it to a storage site, and storing it permanently and safely underground. The CCS value chain consists of three distinct but interconnected elements: capture, transport, and storage which together make up the full CCS value chain.

CAPTURE

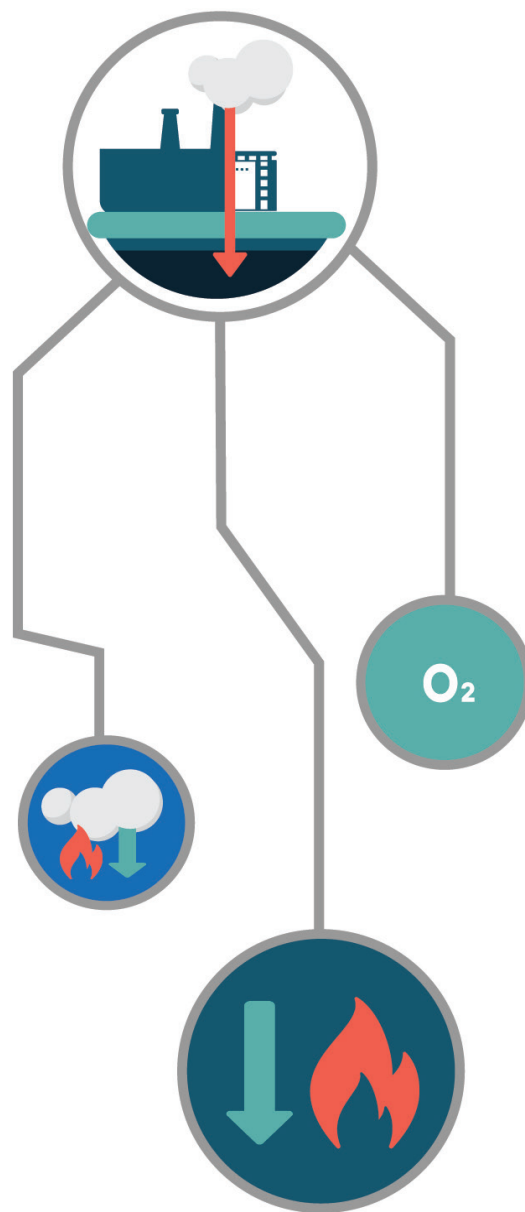
CO₂ capture technologies prevent CO₂ from being released into the atmosphere by capturing it from point sources. The choice of capture technology for an individual industrial site will depend on the design and process conditions of that site.

Capture technologies can be classified into three main categories:

The first group, **post-combustion**, is characterised by the capture of CO₂ from the flue gas stream resulting from fuel combustion or from the chemical processes associated with the treatment of carbon-containing raw materials. Due to the low content of CO₂ in flue gases, its capture requires additional energy, which increases the operating costs of the manufacturing process. It is the most common type of CO₂ capture technology today. Existing industrial sites can be retrofitted in order to apply post-combustion CO₂, as opposed to categories of CO₂ capture which need to be part of the original design of the plant.

In the second group, **pre-combustion**, CO₂ is removed from the fuel or raw material, before it is combusted or processed. Finally, **oxyfuel combustion** is the third category of CO₂ capture and is based on the use of oxygen in the combustion process, which yields a CO₂-rich gas stream making it easier to capture and reducing the cost of the process.

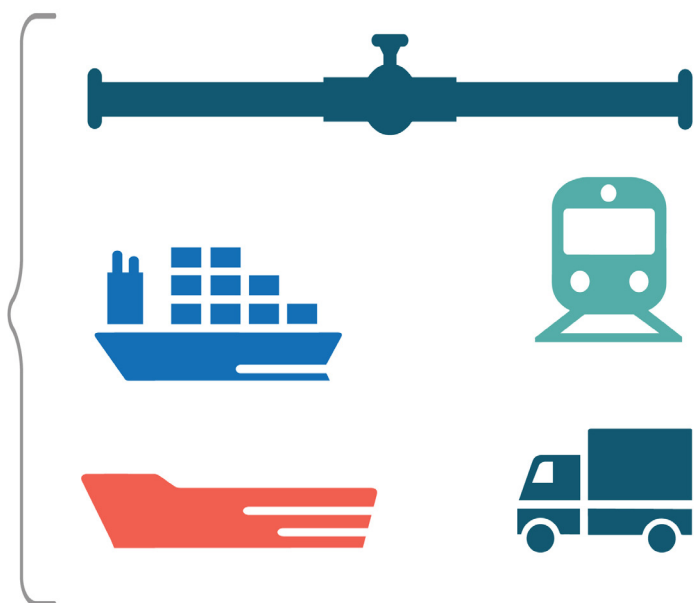
There is a growing number of existing plants and planned projects applying all above-mentioned CO₂ capture technologies, including the production of ammonia, cement, power generation, and waste incineration plants.



TRANSPORT

CO₂ can be transported in various phases (solid, gaseous, liquid and dense/supercritical) and by multiple modes (pipeline, ship, train, truck or barge, or a combination thereof), depending on the CO₂ volume, the location of the capture and the storage sites, the topography of the terrain and the distance between these sites.

Pipelines can move larger volumes of CO₂ than alternative modes of transport over the same distance and in the same amount of time. This favours large emitters and industrial clusters. However, pipelines are capital intensive and limit the flexibility of transport routes, requiring larger volumes to keep operational costs low.



STORAGE

Ship, truck and rail transport of CO₂ are currently used in commercial applications of CO₂ in the food and drink industry but could be scaled up to complement a European CCS infrastructure network. Multimodal transport of CO₂ is already being planned to be used as part of the planned Longship project connecting a cement and a waste-to-energy plant in Norway via road, ship and pipeline-based transport networks. Forming industrial clusters and the coordinated development of CO₂ storage sites are important for rapid and efficient CCS deployment because they can reduce costs by enabling the sharing of infrastructure, transportation networks, and knowledge among industries and other stakeholders. Clustering can create economies of scale, making CCS projects more economically viable.

For offshore storage and intermediate maritime connections within a larger CO₂ transport network, ships can offer much-needed flexibility and adapt more easily to scaling up CO₂ volumes.

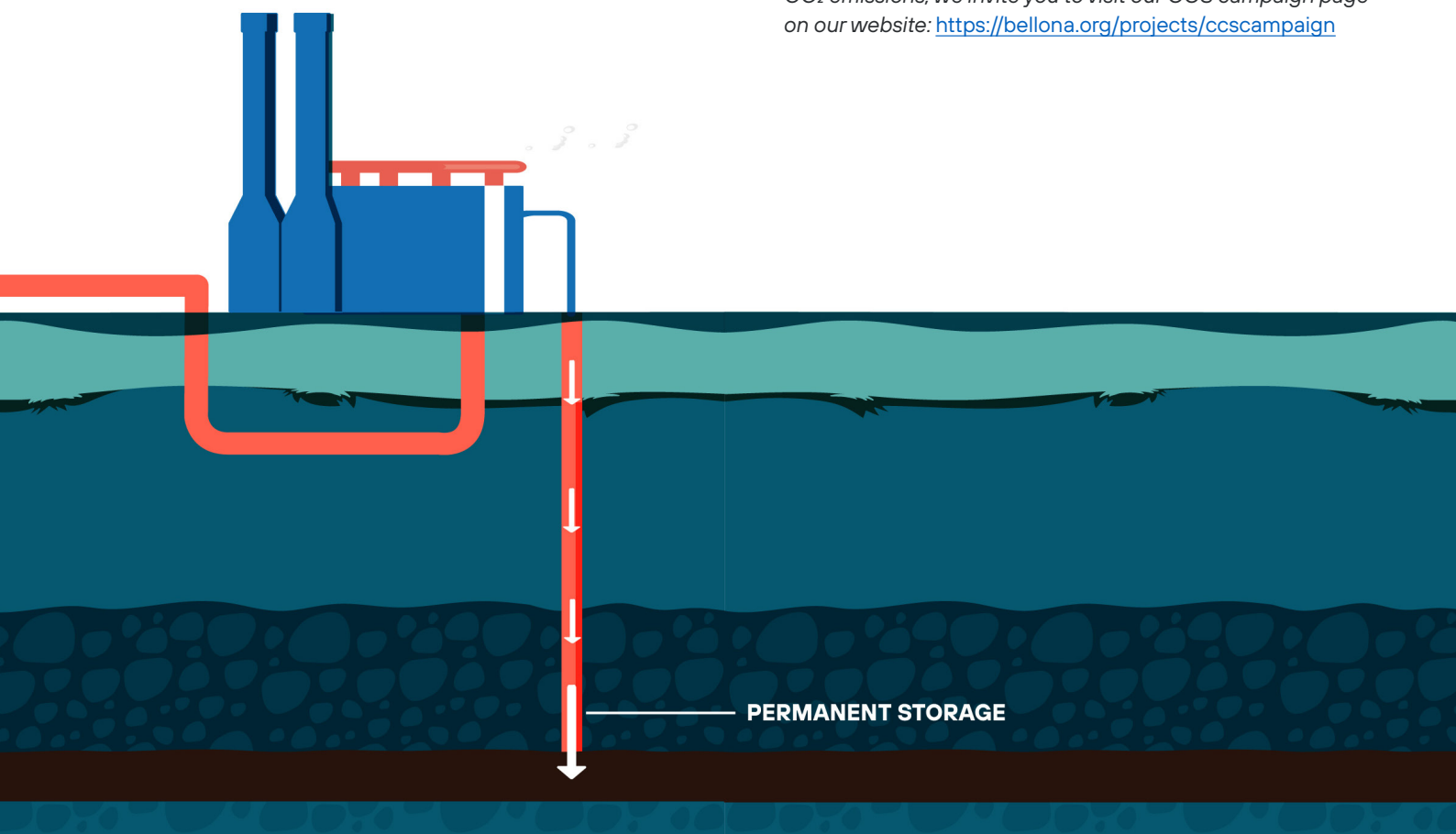
Storage is the final stage of the CCS value chain and an ultimate way to keep captured CO₂ permanently away from the atmosphere. In most cases, CO₂ is injected into geological formations such as deep saline aquifers. Alternatives to aquifers include depleted oil and gas reservoirs or igneous rocks. When it comes to CO₂ storage, the key to success is to map,

model and evaluate the specific site for storage in terms of its ability to contain the required volumes of injected CO₂ in a stable state over centuries and millennia. Key determinants of geological formations' suitability for permanently storing CO₂ include porosity and permeability, capacity and depth, geological stability, seal integrity, and accessibility.

In a well-regulated environment, such as in the EU through the CO₂ Storage Directive, the risks of leakage are very small, and manageable. Geological CO₂ storage is proven to be safe¹⁶ and global storage potential is adequate for CCS to significantly contribute to mitigating the effects of climate change.¹⁷

In summary, CCS is an essential technology that can help reduce CO₂ emissions primarily from industrial processes. CCS can play an important role in mitigating climate change while enabling the transition to a low-carbon economy. While there are still challenges to overcome CCS has the potential to be an important part of the solution in Europe to address the global climate crisis.

For a deeper dive into CCS and the role it can play in reducing CO₂ emissions, we invite you to visit our CCS campaign page on our website: <https://bellona.org/projects/ccscampaign>



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