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

JUNE 2023

Nearly all climate change modelling scenarios highlight that CO_2 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 CO_2 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 emissions[ii] 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, CO_2 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 CO_2 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 CO_2 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 CO_2[5], of which approximately 60% if the result of the calcination process.[6]

7% STEEL

Steel production is responsible for 7% of the global CO_2 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 CO_2 emissions[8] increasing energy efficiency and using BATs can decrease to fully decarbonise steelmaking[9]. This is where CCS technologies come into play,[10] at least in the foreseeable future (around the early 2040s).

2.5% CHEMICALS

Direct CO_2 emissions from the chemical industry claimed 2.5% of global CO_2 emissions (2019).[11] Europe is the second largest chemicals producer in the world.[12] A quarter of the CO_2 emissions are a result of chemical reactions inherent to production.[13] CO_2 is also emitted during the production of ammonia, which is used for fertilisers or purifying water supplies.[14]

CO_2 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]

Photo credit: Adobe Images Gui Yong Niangui Yong Nian

CONTENTS

CCS: A KEY TECHNOLOGY FOR INDUSTRIAL DECARBONISATION	1
BREAKING BARRIERS TO SCALE UP CCS	2
THE CCS PARADOX	2
CAPTURE	3
TRANSPORT	3
STORAGE	4

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 CO_2 Storage Directive, which sets out the legal framework for safe CO_2 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 CO_2 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.

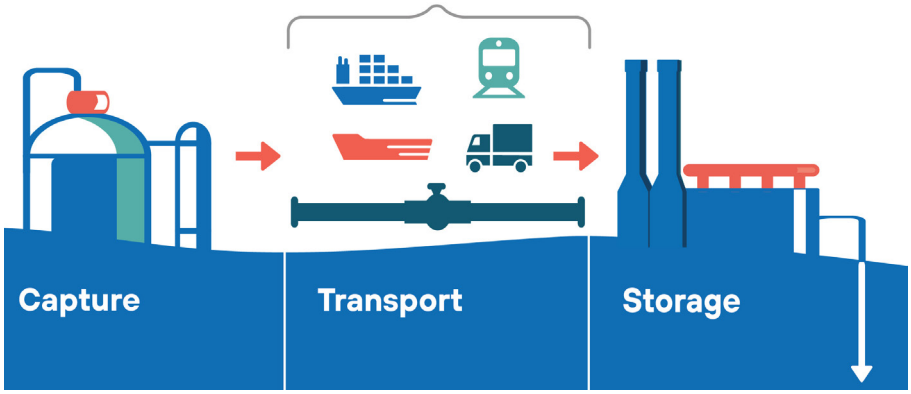
The EU and a number of its Member States are taking active steps to promote the development and deployment of CCS as part of their efforts to achieve net-zero emissions. Policies and initiatives vary between countries but share the common goal of supporting the transition to a low-carbon economy and 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: CO_2 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 CO_2 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 CO_2 storage capacity, for which a reliable supply of captured CO_2 would be necessary as an incentive. At the same time, to boost investment in the capture of CO_2 it is necessary to have the insurance of knowing that storage sites are under development and will be ready to transport and store CO_2 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 CO_2, 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

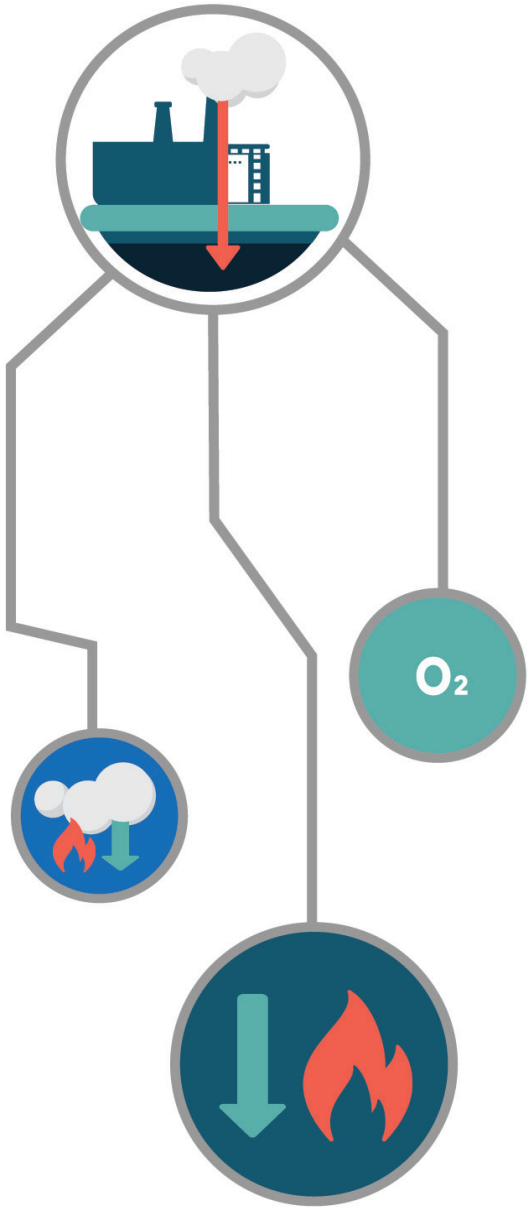
CO_2 capture technologies prevent CO_2 from being released into the atmosphere by capturing it from point sources. The choice of capture technology for an individual industrial site will depend on the design and process conditions of that site.

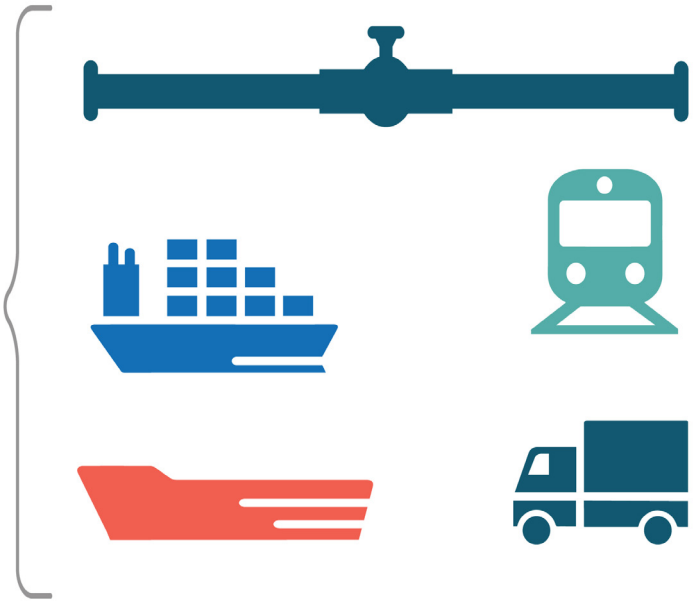
Capture technologies can be classified into three main categories:

The first group, **post-combustion**, is characterised by the capture of CO_2 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 CO_2 in flue gases, its capture requires additional energy, which increases the operating costs of the manufacturing process. It is the most common type of CO_2 capture technology today. Existing industrial sites can be retrofitted in order to apply post-combustion CO_2, as opposed to categories of CO_2 capture which need to be part of the original design of the plant.

In the second group, **pre-combustion**, CO_2 is removed from the fuel or raw material, before it is combusted or processed. Finally, **oxyfuel combustion** is the third category of CO_2 capture and is based on the use of oxygen in the combustion process, which yields a CO_2-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 CO_2 capture technologies, including the production of ammonia, cement, power generation, and waste incineration plants.





TRANSPORT

CO_2 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 CO_2 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 CO_2 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 CO_2 are currently used in commercial applications of CO_2 in the food and drink industry but could be scaled up to complement a European CCS infrastructure network. Multimodal transport of CO_2 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 CO_2 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.

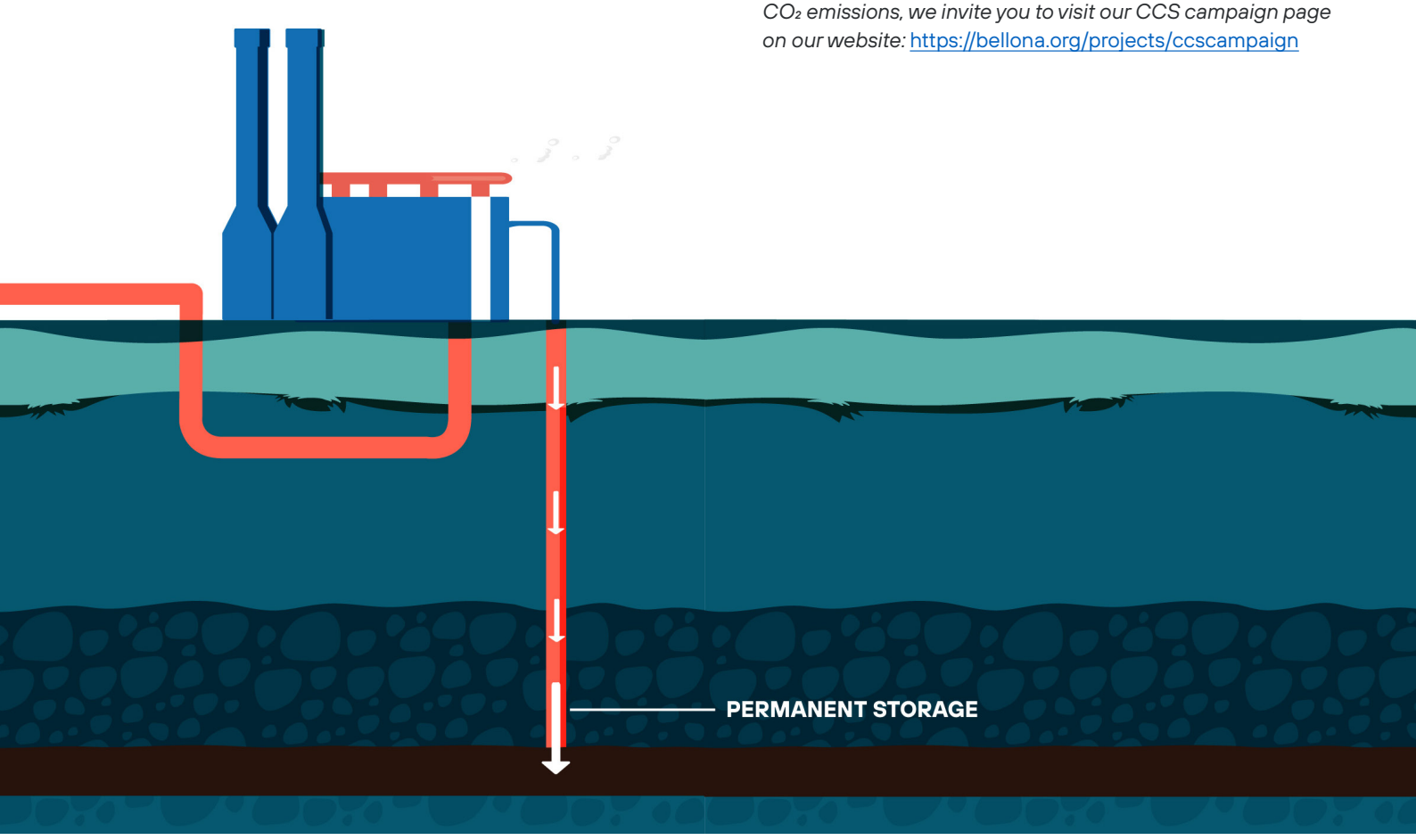
For offshore storage and intermediate maritime connections within a larger CO_2 transport network, ships can offer much-needed flexibility and adapt more easily to scaling up CO_2 volumes.

Storage is the final stage of the CCS value chain and an ultimate way to keep captured CO_2 permanently away from the atmosphere. In most cases, CO_2 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 CO_2 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 CO_2 in a stable state over centuries and millennia. Key determinants of geological formations' suitability for permanently storing CO_2 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 CO_2 Storage Directive, the risks of leakage are very small, and manageable. Geological CO_2 storage is proven to be safe[16] 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 CO_2 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 CO_2 emissions, we invite you to visit our CCS campaign page on our website: https://bellona.org/projects/ccscampaign



REFERENCES

1. IPCC, 2023: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf

2. European Commission, 2018: IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773: A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy., com_2018_733_analysis_in_support_en.pdf (europa.eu)

3. CHATHAM HOUSE, 2018: Making Concrete Change: Innovation in Low-carbon Cement and Concrete. [Authors: J. Lehne, F Preston], Making Concrete Change: Innovation in Low-carbon Cement and Concrete | Chatham House – International Affairs Think Tank

4. IEA, 2022: Cement, IEA, Paris https://www.iea.org/reports/cement License: CC BY 4.0

5. Ibid.

6. Bellona Foundation, 2018: An Industry's Guide to Climate Action. [Authors: J. Andreas, A. Šerdoner, K. Whiriskey], Industry-Report-final.pdf (bellona.org)

7. IEA, 2020: Iron and Steel Technology Roadmap, IEA, Paris https://www.iea.org/reports/iron-and-steel-technology-roadmap, License: CC BY 4.0

8. Ibid.

9. Ibid.

10. Ibid.

11. IEA, 2022: Chemicals, IEA, Paris https://www.iea.org/reports/chemicals, License: CC BY 4.0

12. CEFIC, 2021: Profile: Europe is the second largest chemicals producer in the world, Profile - cefic.org

13. IEA, 2022: Chemicals, IEA, Paris https://www.iea.org/reports/chemicals, License: CC BY 4.0

14. Ibid.

15. Ibid.

16. Kivi, I. R., Makhnenko, R. Y., Oldenburg, C. M., Rutqvist, J., & Vilarrasa, V., 2022: Multi-layered systems for permanent geologic storage of CO2 at the gigatonne scale., Geophysical Research Letters, 49, e2022GL100443. https://doi.org/10.1029/2022GL100443

17. IPCC, 2023: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf

CONTACT

Lina Strandvåg Nagell
Senior Manager Projects & EU Policy

Phone
Mobile: +32 (0) 489 638 843

Online
Email: lina@bellona.org
Website: www.bellona.org

Aravind Dhakshinamoorthy
Policy Analyst

Phone
Mobile: +32 04 86 13 98 40

Online
Email: aravind@bellona.org
Website: www.bellona.org

Hanna Biro
Policy Analyst

Phone
Mobile: +32 (0) 467 754 344

Online
Email: hanna@bellona.org
Website: www.bellona.org

Bellona Europa is an independent, non-profit organisation that meets environmental and climate challenges head on. We are solutions-oriented and have a comprehensive and cross-sectoral approach to assess the economics, climate impacts and technical feasibility of necessary climate actions. To do this, we work with civil society, academia, governments, institutions, and industries.