

SDG 7, affordable and clean energy: Carbon Capture and Storage

Carbon Capture, Utilisation, and Storage (CCUS) technologies are crucial to achieving the EU's 2050 climate objectives. Although the EU has targets focusing on reducing carbon emissions, such as in the electricity sector by switching to renewables, or using natural gas instead of highly polluting coal, some industries are more challenging to decarbonise, including cement, steel, pulp and paper, and chemicals. There, the technology of capturing emissions and storing them or utilising them as inputs to new processes offers important improvements.

The concept of achieving 'net zero' carbon emissions does not imply the complete elimination of CO₂ emissions. Rather, it refers to a balance where the amount of CO₂ released into the atmosphere through human-caused activity is offset by an equivalent amount being removed, either through natural processes or technological solutions.

After a period of limited progress, CCUS technologies are now experiencing renewed momentum globally. According to the Global Status of CCS 2025 report (Global CCS Institute 2025), there are 77 commercial CCS projects in operation, 47 under construction, 610 in development, and another 737 under consideration. The global capture capacity reached 64 million tonnes per annum (MTPA) in July 2025, while according to the International Energy Agency (IEA) estimate, 7.6 Gt annually are needed by 2050 to achieve net-zero emissions (IEA 2021).

Carbon dioxide removal (CDR) strategies can be broadly categorised into two main groups: ecosystem-based approaches and industrial technologies.

Ecosystem-Based Approaches

Forests act as natural carbon sinks by absorbing CO₂ through photosynthesis and storing it in biomass and soil. Afforestation, the process of planting trees on land not previously forested, is considered a relatively low-cost CDR approach. However, it is constrained by land availability and long-term land-use pressures.

Wetlands, including marshes, peatlands, and coastal ecosystems, serve as significant carbon sinks by accumulating organic material under anaerobic conditions that slow decomposition rates. The potential for large-scale wetland restoration is geographically



constrained and entails moderate costs; however, these ecosystems offer multiple co-benefits, including biodiversity conservation, flood mitigation, and water purification.

Another solution is the creation of biochar, a stable, carbon-rich material produced by heating organic biomass in a low-oxygen environment, a process known as pyrolysis. Similar in composition to charcoal, biochar can be used as a soil amendment, improving soil health and sequestering carbon over long periods. The effectiveness of biochar as a CDR technique depends on the feedstock used, production conditions, and soil characteristics, but it offers promising potential, particularly in agricultural regions.

Several innovative strategies seek to harness oceanic processes to remove carbon from the atmosphere: Ocean Alkalinity Enhancement, Ocean Fertilisation, Artificial Upwelling and Downwelling, and Macroalgae Cultivation.

Ocean Alkalinity Enhancement involves adding alkaline substances (such as crushed minerals) to seawater, promoting the conversion of dissolved CO₂ into stable carbonate forms that sink to the seafloor. This approach has strong potential for scalability and moderate costs, but requires careful evaluation of ecological impacts.

Ocean Fertilisation, particularly with iron or phosphorus, stimulates phytoplankton growth. As these microscopic organisms perform photosynthesis, they absorb carbon dioxide from the atmosphere. When they die, a portion of the carbon they contain sinks to the ocean floor. While relatively inexpensive, this method is subject to ecological uncertainties and regulatory scrutiny due to its potential to disrupt marine ecosystems.

Artificial Upwelling and Downwelling utilises submerged pipes to circulate seawater. Nutrient-rich water from the ocean depths is brought to the surface to enhance phytoplankton productivity, while surface water is simultaneously pushed downward to deliver oxygen and deter the formation of hypoxic (dead) zones. This technique is more costly and has limited deployment potential compared to other ocean-based methods.

Macroalgae Cultivation (e.g., seaweed farming) also represents a viable CDR strategy. Like phytoplankton, macroalgae absorb CO₂ through photosynthesis. They also have growing commercial applications in food, biofuels, and materials, creating economic incentives for large-scale cultivation and long-term carbon storage through biomass sinking or processing.

Industrial Methods

Technological carbon removal methods provide opportunities for large-scale CO₂ management, especially in sectors where emissions are hard to abate. Carbon Capture and



Storage (CCS) involves capturing CO₂ at the point of emission (e.g., power plants or industrial facilities), compressing it, and injecting it into geological formations for long-term storage. CCS is technically mature and already in use, though it remains costly and requires extensive infrastructure. Carbon Capture, Utilisation, and Storage (CCUS) builds on CCS by incorporating pathways to convert captured CO₂ into valuable products, such as fuels, chemicals, or building materials. While CCUS can generate economic value, the permanence of the CO₂ sequestration varies depending on the end use.

Bioenergy with Carbon Capture and Storage (BECCS) and its variant BECCUS, which adds Utilisation, integrate biomass-based energy production with carbon capture. Since the biomass used has absorbed atmospheric CO₂ during its growth, capturing and storing the emissions from its combustion results in a net negative emission. These systems are considered crucial in many net-zero models, though their feasibility is contingent on sustainable biomass sourcing and land-use considerations.

Direct Air Capture (DAC) refers to technologies designed to extract carbon dioxide directly from the atmosphere. These systems often involve large installations, comparable to wind tunnels or towers, through which ambient air is passed and exposed to chemical sorbents or solvents that selectively bind CO₂. Once captured, the concentrated CO₂ is typically compressed and transported for geological storage, for instance, in depleted natural gas reservoirs or disused mine shafts (Terlouw et al. 2021). This approach offers a high degree of permanence and the potential for negative emissions, though current costs and energy requirements remain high.

Carbfix: Permanent Carbon Storage through Mineralisation

While forests and other ecosystems provide important carbon sinks, nature also stores vast amounts of carbon within geological formations – particularly in rock. Leveraging this natural process, the Carbfix project offers a scientifically innovative method for permanent carbon dioxide removal through in-situ mineralisation.

Carbfix is a carbon capture and storage (CCS) technology developed in Iceland that mimics and accelerates the natural process by which CO₂ becomes locked into rocks over geological timescales. The method involves dissolving CO₂ in water and injecting this carbonated water into basaltic rock formations that are rich in calcium, magnesium, and iron. Once injected, the CO₂ reacts with the basalt to form stable carbonate minerals, effectively transforming the gas into solid rock within just two years (Matter et al. 2016). Unlike



conventional CCS, where CO₂ is injected into underground reservoirs as a supercritical fluid and stored under pressure (IPCC 2018), Carbfix operates at low temperatures and ambient pressures. The process requires three ingredients: appropriate porous rock, typically basalt, which is abundant in Iceland, water, and captured carbon dioxide. This geochemical reaction sequesters carbon permanently, as reversing the process would require extreme conditions not found in the subsurface environment. The challenge lies in the source of water, as the process utilises freshwater, while the CO₂ must first be dissolved before injection. However, ongoing research is being conducted on the use of saltwater as an alternative to decrease the environmental impact, and in 2023, the first injection using seawater was performed (Carbfix n.d.).

Carbfix began as a research project in 2006 and since then has evolved into a fully operational industrial process. The company has two operating sites, the most well-known of which is Hellisheiði, where the pilot injections were tested, and Carbfix's pilot CCS plant at ON Power's geothermal site in Nesjavellir, Iceland, which started operations in 2023.

The flagship implementation of Carbfix is at the Hellisheiði geothermal power plant near Reykjavik. Carbfix started pilot injections of CO₂ at Hellisheiði in 2012. Since then, almost 100,000 tonnes of captured carbon dioxide have been stored at the site. The EU CCS Directive adopted in 2009 (EU 2009) does not require storage permits for below 100,000 tonnes when the storage is part of research and development testing. In collaboration with Reykjavik Energy and several academic partners, Carbfix has demonstrated the feasibility of injecting CO₂ into the nearby basalt formations. According to Matter et al. (2016), over 95% of the CO₂ injected at depths between 400 and 800 m was mineralised within two years, validating both the speed and permanence of the process. As of 2023, Carbfix has safely injected over 100,000 tonnes of CO₂ and is scaling up operations as part of broader European and global decarbonisation efforts.

In April 2025, Carbfix obtained a permit from the Environment and Energy Agency of Iceland for the on-site storage of up to 106,000 tonnes of CO₂ per year, which is 3.2 MTPA over thirty years (Carbfix 2025), in a storage area located next to the geothermal area in Hellisheiði (UOS 2025). This marks the issuance of the first permit for carbon dioxide storage in Europe at an onshore site.

Carbfix stores CO₂ from two sources that are located at the site: ON Power's geothermal power plant, which is among the world's largest, and Climeworks' two direct air capture plants, the larger of which is the world's largest direct air capture facility in operation. With the permit in place, it is now possible to capture and store all CO₂ emissions from the Hellisheiði Power Plant.

Social acceptance – Coda Terminal in Hafnarfjörður

Carbfix was planning to open Coda Terminal, the first commercial onshore carbon dioxide reception and storage facility, in the city of Hafnarfjörður, Iceland, near the capital region.¹

The aim of the project was to receive cargo ships carrying carbon dioxide and inject it into the ground, where it would bind to rock layers using a fast mineralisation method that the company has developed. The storage was expected to hold three million tonnes of injected CO₂ (Grettisson 2025). The project required new harbour infrastructure to receive international shipments of CO₂. The expansion of the harbour in Straumsvík in Hafnafjordi was considered a prerequisite for the Coda Terminal and was supposed to be managed by Hafnarfjörður's port authority and municipal government.

In 2022, the Coda Terminal received an EU Innovation grant of EUR 115 million, and the discussions with the Hafnarfjörður municipal council were ongoing. The Environmental Assessment Agency submitted its opinion on the project's environmental impact assessment and proposed seventeen conditions for the operating permit. Most of these conditions concerned the monitoring and supervision of the operation's impacts, especially on the tidal ponds in Straumsvík, seismic activity, and groundwater levels (Kjartarsson 2025).

As part of the dialogue with the local population, an online consultation forum was created and is available on the Carbfix webpage, providing information on the Coda Terminal project. It contains information about briefings for the residents of the Hafnarfjörður municipality, during which the project was introduced and discussed. The project and the environmental assessment report were also publicly advertised in local newspapers. The environmental assessment report was available on the Planning Agency's website. A presentation meeting about the project was held on June 20, 2024, in Hafnarfjörður.

The Planning Agency sought the opinion of various stakeholders: Hafnarfjörður town, the Marine Research Institute, the Health Inspectorate of Garðabær, Hafnarfjörður, Kópavogur, Mosfellsbær and Seltjarnarnes, the Icelandic Heritage Institute, the Icelandic Institute of Natural History, the Environmental Institute, and the Icelandic Road Administration.

Comments on the Environmental Assessment Report were received from: Hafnarfjörður Municipality, Marine Research Institute, Health Inspectorate of Garðabær, Hafnarfjörður,

¹ Hafnarfjörður has population of 31,525, making it the third largest municipality in Iceland.



Kópavogur, Mosfellsbær and Seltjarnarness, Icelandic Antiquities Authority, Icelandic Institute of Natural History, Environment Agency, Road Administration, and twenty individuals (Skipulagsgatt 2025).

However, the project was ultimately cancelled due to vocal opposition from the residents. Several opinion pieces were published in local media arguing against the project, addressing potential harmful effects on the environment and local seismic activity (Hafnafjordur 2025). It is not yet known if the EU grant for Coda Terminal can be used when the project location has changed. The company will focus on other locations for its projects.

Questions

1. Is carbon capture a valid excuse for fossil fuel companies (gas and oil) to continue operations?
2. Would it be better to close the fossil fuel companies rather than create industrial CCS?
3. Which SDGs does Carbifix support?
4. How does Carbifix align with SDG 7?
5. Should Iceland allow the import of carbon dioxide from other countries, or should it focus on reducing its own emissions?
6. How relevant is consumers' acceptance of new technologies? Discuss the example of Coda Terminal.

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