# Carbon Capture, Storage and Utilization: Transforming Emissions into Solutions

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## Overview

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- CCUS technologies involve capturing $CO_2$ emissions from industrial processes, utilizing it in various ways, and storing it permanently underground.

- CCUS provides a cost-effective way to reduce GHG emissions from industrial processes, thereby contributing to the fight against climate change.

- CCUS projects under development are increasingly geographically diverse, with more than 30 countries now involved, and the proliferation of decarbonization targets for the global economy by 2050 is prompting the expansion of $CO_2$ capture applications.

Carbon Capture Utilization and Storage (CCUS) technologies have been gaining increasing traction in recent years as an effective way to reduce greenhouse gas (GHG) emissions and mitigate climate change. These technologies involve capturing $CO_2$ emissions from industrial processes, utilizing it in various ways, and storing it permanently underground, thereby reducing the amount of $CO_2$ that is released into the atmosphere.

The CCUS process can be divided into three primary stages: capture, utilization, and storage. The first stage involves the capture of $CO_2$ emissions from industrial sources such as power plants, cement plants, and refineries. Various methods are used to capture $CO_2$ emissions, including post-combustion capture, pre-combustion capture, and oxyfuel combustion.

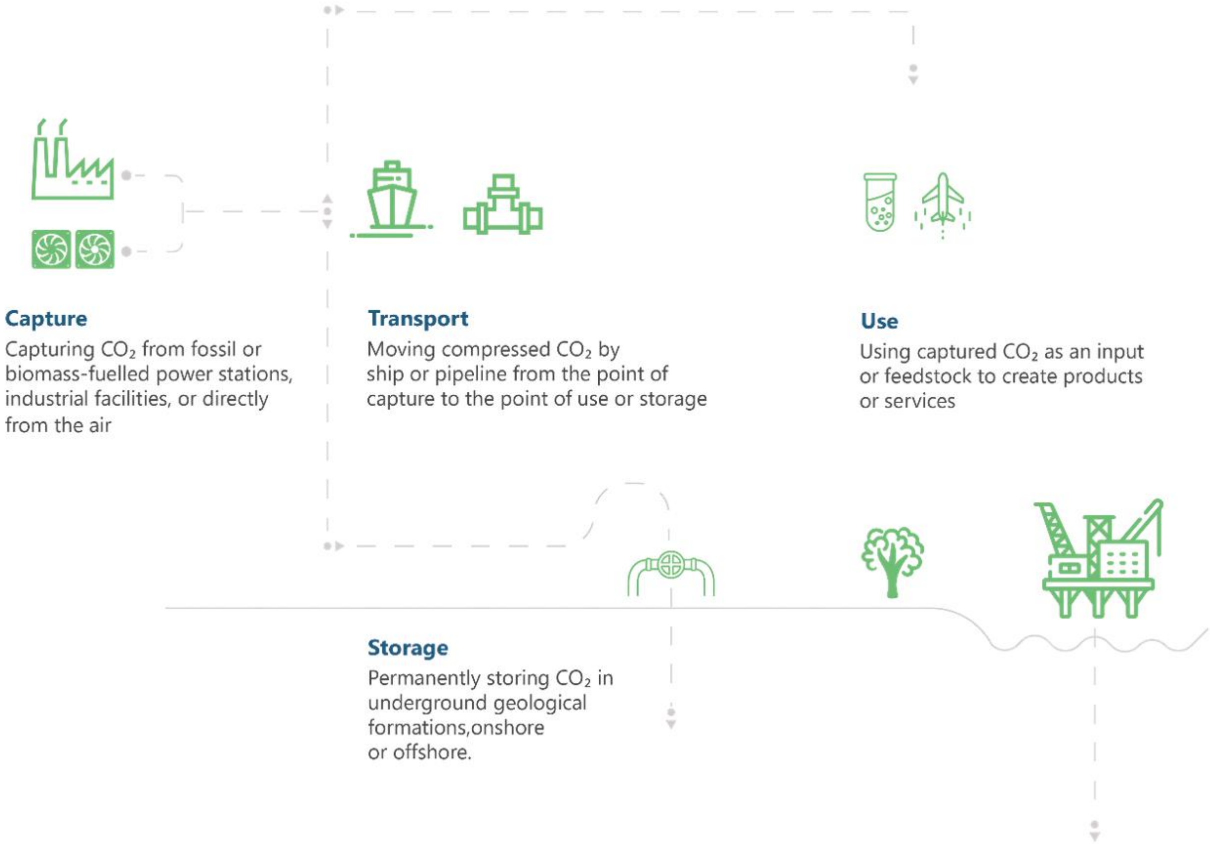


*Figure 1: The CCUS process*

The second stage is the utilization of the captured CO2, which involves utilizing it in various applications such as enhanced oil recovery (EOR), chemical production, and building materials. For instance, CO2 can be used in the production of methanol, fertilizers, and cement, which can significantly reduce the carbon footprint of these products.

The third stage is the storage of the captured CO2. The most common storage method is underground storage, where the CO2 is injected into geological formations such as depleted oil and gas reservoirs, deep saline formations, and coal seams that cannot be mined. The CO2 is then trapped underground and prevented from entering the atmosphere, thereby reducing GHG emissions.

CCUS technologies have numerous advantages. Firstly, they provide a cost-effective way to reduce GHG emissions from industrial processes, thereby contributing to the fight against climate change. Secondly, the use of CO2 in various applications can help create new industries and jobs while also reducing the carbon footprint of these products. Finally, the storage of CO2 underground can help address concerns about global warming and its potential impact on the environment.

It should be noted that CO2 usage for commercial products or services, like Enhanced Oil Recovery, may not always deliver a net climate benefit. Most CCUS projects are dedicated to CO2 storage, rather than usage. When considering CO2 usage, it is important to assess its impact on the overall carbon budget. While CO2 usage offers potential, the immediate focus should be on securing permanent storage for captured CO2 to achieve large-scale emission reductions.

# Current Potential and Opportunities

Despite being recognized as crucial for achieving climate goals, CCUS has yet to fulfill its potential, according to the IEA. Deployment has been sluggish, with annual CCUS investment accounting for less than 0.5% of global investment in clean energy and efficiency technologies.

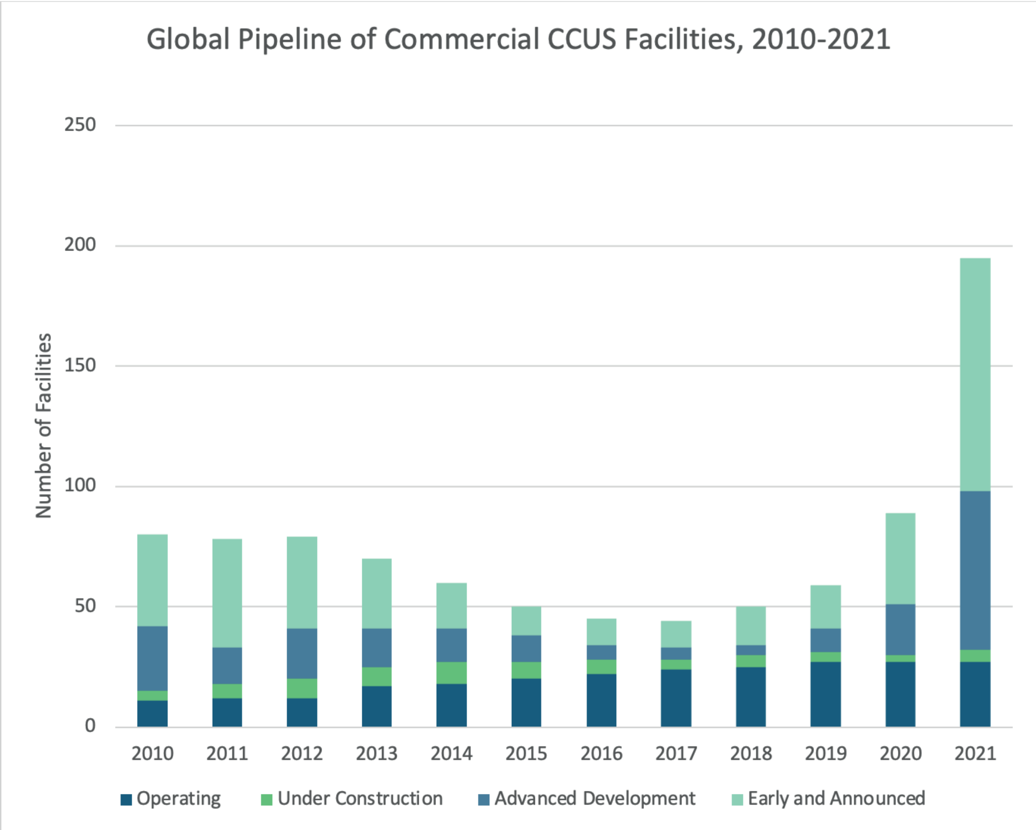


*Figure 2: Global Pipeline of Commercial CCUS Facilities Operating and in Development.*
*Source: International Energy Agency (IEA)*

However, the proliferation of decarbonization targets for the global economy by 2050 is prompting the expansion of $CO_2$ capture applications. Presently, a significant portion (65%) of $CO_2$ capture capacity is located at natural gas processing plants, which offer a low-cost option for carbon capture. However, new CCUS developments are now aimed at different applications. As per the existing project pipeline, the annual capture capacity by 2030 from new construction and retrofitting could reach approximately 70 Mt $CO_2$ from power generation, 70 Mt $CO_2$ from hydrogen production, and 20 Mt $CO_2$ from industrial facilities (such as cement, steel, and chemicals). Bioenergy with carbon capture and storage (BECCS) and direct air capture (DAC) with $CO_2$ storage are the essential technologies for carbon removal. Globally, over 40 bioethanol facilities, which are among the least expensive BECCS applications, have plans to capture $CO_2$, and around 15 biomass and waste-fired combined heat and power plants could be capturing about 15 Mt $CO_2$ by 2030. The United States will inaugurate its first megaton-scale DAC plant in 2024.

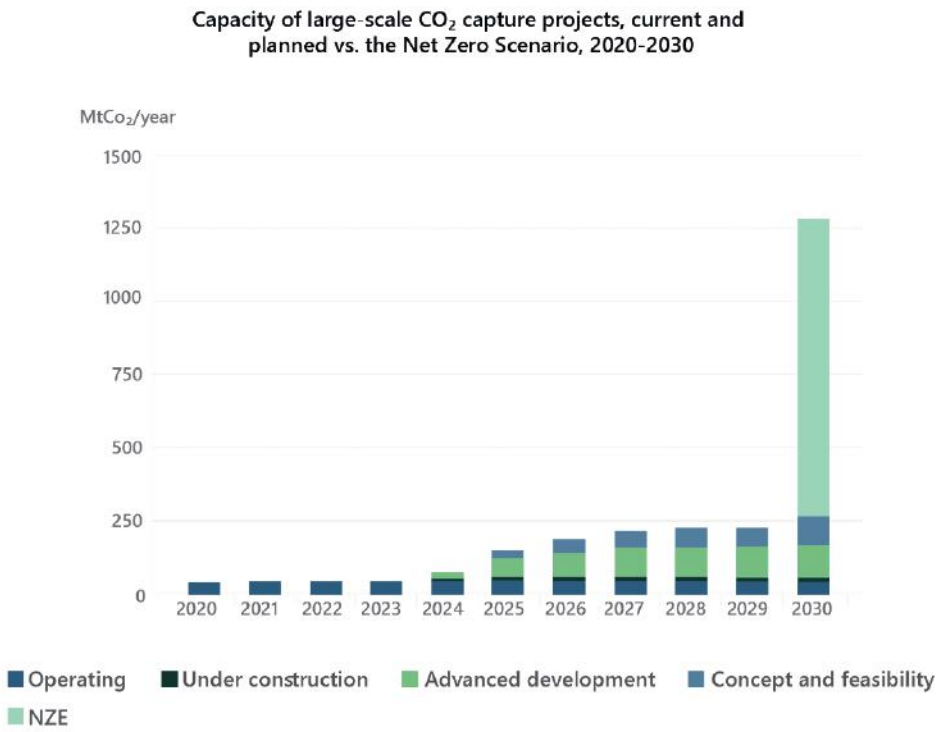


*Figure 3: Capacity of large-scale CO2 capture projects, current and planned vs. the Net Scenario, 2020-2030.*
*Source: iea*

According to the IEA, CCUS projects under development are increasingly geographically diverse, with more than 30 countries now involved. In Southeast Asia, over 10 projects in Indonesia, Malaysia, and Thailand, most of which were announced since January 2020, could result in a total capture capacity of approximately 15 Mt $CO_2$ per year by 2030. In China, the Sinopec Qilu Petrochemical project completed construction in January 2022, while the first Chinese offshore CCUS project, announced in September 2021, completed construction in June 2022. In North America, the United States has approximately 80 projects aiming for operation before 2030, potentially increasing its $CO_2$ capture capacity almost five-fold, from over 20 Mt $CO_2$ to over 100 Mt $CO_2$ per year. In Canada, around 15 projects are in different phases of development. In Europe, policy support and decarbonization targets have spurred CCUS development, particularly in industrial clusters linked to $CO_2$ storage hubs. About 50 projects could be capturing almost 70 Mt $CO_2$ per year by 2030 in Norway, the United Kingdom, the Netherlands, Sweden, and Denmark, primarily around the North Sea. In the Middle East, four additional projects are under development, in addition to the four already operational. Bahrain recently announced plans to implement CCUS at an aluminum plant, which would be the first application of CCUS to aluminum. Qatar's North Field East LNG project construction continues, expected to expand CCUS capacity from over 2 Mt $CO_2$ per year to 5 Mt $CO_2$ by 2050.

## Companies Engaged in CCUS

Investing in companies that specialize in carbon capture technology could prove to be a profitable decision, as the renewable energy industry, particularly in Asia, is projected to grow steadily. Currently, larger publicly traded companies, such as Shell, ExxonMobile, Chevron, Dow, INEOS, and Marathon Petroleum, invest in smaller CCS companies, providing a way for regular investors to get involved.

As of 2020, a total of 21 large-scale carbon capture companies are currently operational, with the majority

found in the United States, Canada, the Middle East, and Norway.
There are two main types of CCUS companies out there: those that store and those that utilize captured carbon. CarbFix, for example, captures CO2 at a source, dissolves it in water and pumps it underground. Other companies, such as Carbon Engineering, mix carbon with hydrogen to get eFuels – an alternative to fossil fuels.

1. **CarbFix**, based in Iceland, was established in 2014 and uses source-capture and storage technology and has captured 1 Billion tons of $CO_2$ over its lifetime.

2. **CarbonFree**, located in the US, was established in 2015 and uses direct capture and utilization technology to capture 800 Million tons of $CO_2$ annually.

3. **Quest Carbon Capture and Storage (SHELL)**, located in Canada, was established in 2015 and uses source-capture and storage technology to capture 1.2 Million tons of $CO_2$ annually.

4. **Carbon Engineering**, based in Canada and established in 2009, uses direct CCS and storage and eFuel production technology to capture 1 Million tons of $CO_2$ annually.

5. **Aker Carbon Capture**, located in Norway and established in 2020, uses source-capture and utilization technology to capture 400,000 tons of $CO_2$ annually.

6. **LanzaTech**, based in New Zealand and set up in 2005, uses source-capture and utilization technology to capture 150,000 tons of $CO_2$ annually.

7. **$CO_2$ Solutions by SAIPEM**, found in Canada and established in 1997, uses source-capture and utilization technology to capture 11,000 tons of $CO_2$ annually.

8. **Global Thermostat**, located in the U.S. and established in 2010, uses direct air CCS and utilization technology to capture 4,000 tons of $CO_2$ annually.

9. **Climeworks**, based in Switzerland and established in 2009, uses direct air CCS and storage technology to capture 4,000 tons of $CO_2$ annually.

10. **Net Power**, located in the U.S. and established in 2008, uses Allam-Fetvedt Cycle source-capture and utilization technology to produce electricity, but its carbon capture capacity is not available.

## Future Prospects

North American countries such as the U.S. and Canada, responsible for 65% of yearly capture capacity, have demonstrated unwavering commitment to CCUS by enacting focused policies that encourage CCUS deployment in the near future. In Europe and Asia, CCUS initiatives are sustained through funding programs and recent frameworks. Details of regional commitment to CCUS in the coming years are detailed below:

•**The U.S.**: The Inflation Reduction Act in the U.S. is set to enhance CCUS through the extension and expansion of the 45Q tax credit. The tax credit amount will almost double for CO2 captured from power and industrial plants and more than triple for CO2 captured from DAC. The deadline for qualification to receive the credit has also been extended by seven years to 2033. Furthermore, the Infrastructure Investment and Jobs Act has allocated roughly USD 12 Billion to the CCUS value chain over the next five years, with various policy mechanisms such as R&D funding, loans, and permittingsupport available to provide assistance.

•**Canada**: The proposed investment tax credit for CCUS projects between 2022 and 2030, is outlined in the 2022 federal budget and is valued at approximately 37-60%, varying based on the project type.

•**Europe**: The European Union has sustained its backing for CCUS by implementing regional funding initiatives like the Connecting Europe Facility - Energy and the Innovation Fund. Additionally, they have modified cross-border regulations to encompass $CO_2$ storage. National subsidy plans, such as those in Denmark and the SDE++ in the Netherlands, have also provided support for CCUS undertakings. Regional industrial clusters for CCUS development are being pursued by several countries, such as the UK, Netherlands, and Norway. These clusters offer economic benefits to multiple emitters by allowing them to share transportation and storage infrastructure. The UK government has provided over USD 330 Million in funding for CCUS between 2004-2019, and is providing up to around USD 30 Million of research and development funding to help develop and pilot next generation carbon capture technologies.

•**Asia**: Korea has unveiled its intention to invest as much as USD 1.2 Billion to advance CCUS technologies by 2030. Of this amount, approximately 30% will be utilized to evaluate $CO_2$ storage resources, while the majority of the remaining funds will be allocated to establish a complete offshore CCUS project. Also, in early 2022, Indonesia revealed its plans to create regulations that will establish a legal and regulatory framework for CCUS activities, which will be the first of its kind in the region.

Carbon Taxes and Emissions Trading Systems (ETS) can be harnessed to bolster investment in CCUS and increase its global uptake. Because these carbon pricing strategies act as direct disincentives to produce carbon, companies will look to more sustainable options, such as CCUS, as these become more ubiquitous and stringent.

In conclusion, CCUS technologies have the potential to play a critical role in reducing GHG emissions and mitigating climate change. While there are challenges associated with implementing these technologies, ongoing research and development efforts are expected to address these challenges, making CCUS technologies more cost-effective and efficient in the future.

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