EPRI

Quick Insights

Current Global Barriers to the Deployment of Carbon Capture, Storage, and Utilization (CCUS)

RESEARCH QUESTIONS

What is Carbon Capture, Utilization, and Storage (CCUS)? What is driving the increased interest in CCUS systems, which can be viewed as an integral part of the global decarbonization effort? How can CO_2 utilization play a role in reducing CO_2 emissions? What are some of the current challenges to the implementation of CCUS? What recent global advancements have been made to develop and deploy CCUS technologies? How can proposed legislation within the U.S. help to reduce the initial cost of implementation of CCUS systems?

KEY POINTS

- While CCS (carbon capture and storage) simply refers to the storage of CO_2, CCUS (Carbon Capture, Utilization, and Storage) also includes the utilization of collected CO_2 for purposes other than storage.
- CCUS can play a role in reducing carbon emissions
- CO_2 utilization is viewed as an alternative to traditional storage, and can help to reduce CO_2 emissions across different industries.
- Deployment of CCS technologies has been hindered by cost challenges associated with retrofitting existing power plants and constructing new CCS systems [1].
- More countries have advanced the idea of implementing CCUS systems in recent years, with the number of additional planned CCUS projects growing 48% in the latter half of 2020 alone, increasing total available capacity from 75 Mtpa to 111 Mtpa worldwide [2].
- Within the U.S., proposed updates to the Section 45Q tax credit, as well as the Infrastructure Investment and Jobs Act (IIJA), may provide an incentive for power plants to capture and store CO_2 and help to ease the high cost of CCUS systems [3].
- Despite current potential barriers, CCUS technologies have been identified as key in order to address carbon emission reductions within the coming decades [4].

INTRODUCTION TO CCS POTENTIAL

Carbon capture and storage (CCS) refers to a range of different carbon emission reduction technologies for capturing, transporting, and storing CO_2. CCS can be applied to various energy systems, including power generation facilities that utilize fossil fuels to produce electricity [5]. The captured CO_2 is compressed and transported via pipelines, and stored in underground formations, including abandoned natural gas and oil reservoirs, or saline aquifers [6]. CCS technologies have been operational in the U.S. since the early 1970s, and for example, more than 200 million tons of CO_2 from natural gas production facilities in Texas have safely been stored underground [7]. The three main methods for the capture of CO_2 include pre-combustion, post-combustion, and oxyfuel combustion. The differences between these three primary types of carbon capture technologies is in how CO_2 is separated from other waste gases emitted [1]. Carbon can also be directly captured from the air, through the use of direct air capture (DAC) technologies. If the energy industry continues to rely on fossil fuels as an energy source for the foreseeable future, technologies such as CCS are essential for mitigating CO_2 emissions.

Interest in decarbonization strategies has grown in recent years, as companies seek to implement net-zero technologies across a variety of carbon-emitting industrial sectors. As the world continues to heavily rely on fossil fuels for electricity generation, and for dispatchable generation throughout the energy transition, addressing and reducing power sector emissions will be important. CO_2 removal is a necessary step in order to meet targets set forth by the 2015 Paris Climate Accord. The Intergovernmental Panel on Climate Change (IPCC) identified it will be necessary to remove five to ten gigatons of carbon globally by 2050 in order to remain under the Accord's maximum 1.5-degree Celsius temperature increase goal. The IPCC has emphasized that utilizing CCS as an emissions reduction technology is a crucial piece of the decarbonization equation in terms of meeting emission reductions goals [8].

The graphic below shows there has been an increasing amount of CO_2 storage deployed worldwide, especially over the last two decades [3].

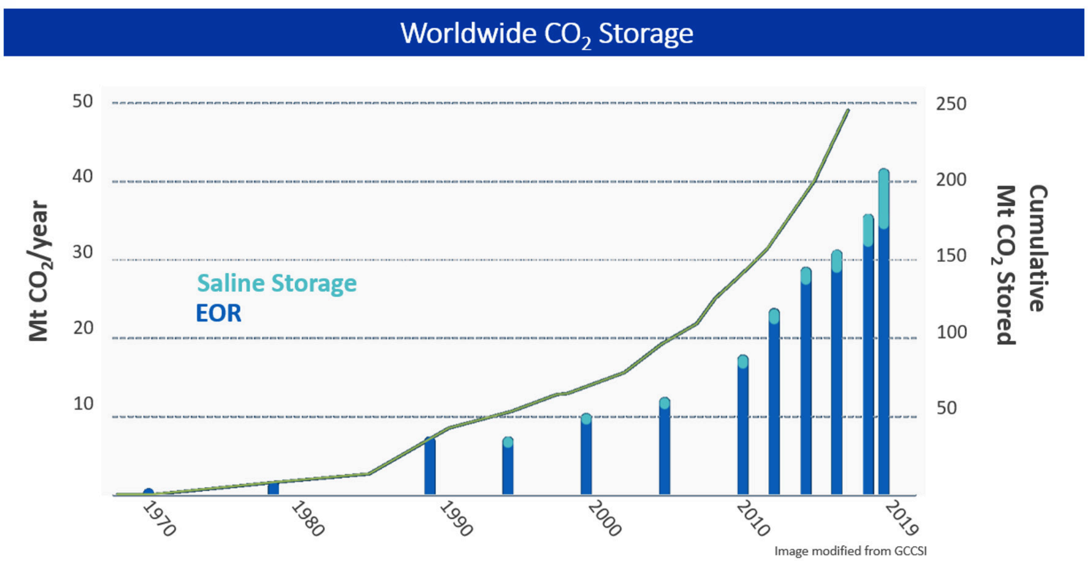

Figure 1: As CO_2 storage has increased, the amount of global CO_2 emissions sequestered from the atmosphere also has increased. Source: [2].

CO_2 UTILIZATION POTENTIAL

Carbon dioxide utilization is the conversion or use of CO_2 to create a usable end product. It is an alternative to traditional CCS methods that employ geologic storage or enhanced oil recovery, where there may be specific environmental concerns or simply not be well-suited geology [4]. The graphic on page 3 outlines various industries and their respective captured CO_2 emissions.

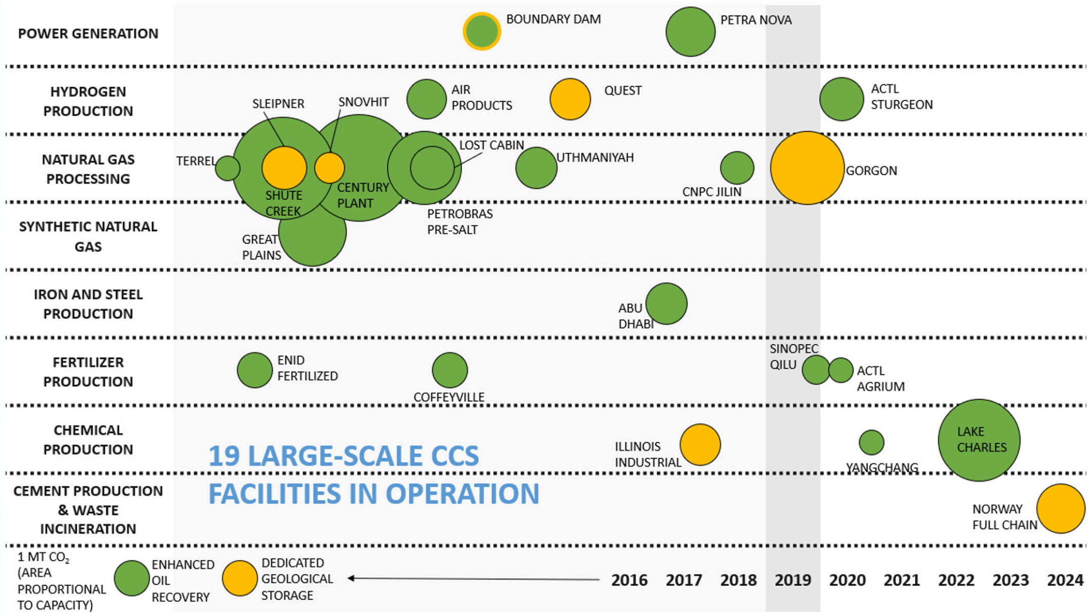

Figure 2: CO_2 emissions currently being captured from existing CCS facilities worldwide. Source: [2].

CHALLENGES TO DEPLOYMENT: COST CONSIDERATIONS

One of the main challenges facing implementation of CCUS technologies is their initial cost. The current cost of installing commercial CCUS technologies is an estimated \$400–500 million per unit, which amounts to \$58.30 per metric tonne of CO_2 [10]. Some experts point out that costs related to CCS technologies will likely decrease over time, from the current amount of \$100–\$150/tonne of CO_2 (which includes initial CCS installation costs, repowering, and SOX control), to just \$30–50/tonne CO_2, as research continues to drive improvements in both capture and storage technologies [11]. The International Energy Agency (IEA) notes, "There is considerable potential to reduce costs along the CCUS value chain, particularly as many applications are still in the early stages of commercialization. Experience indicates that CCUS should become cheaper as the market grows, the technology develops, finance costs fall, economies of scale are reached, and experience of building and operating CCUS facilities accumulates. Cost reductions have already been achieved at large-scale CCUS projects. For example, the cost of CO_2 capture in the power sector has come down by 35% through its evolution from the first to the second large-scale CCUS facility, and this trend is set to continue as the market expands" [12].

The IEA also points out that CCUS technologies do not all have the same associated cost. Highly concentrated streams, which generally contain greater than 1,000 ppm of CO_2, may cost anywhere from \$15-25 USD per ton of CO_2 to process, while more diluted CO_2 stream may have a higher processing cost ranging from \$40–\$120 USD per ton of CO_2 [12]. Carbon transport and storage can also affect costs. Despite potential cost issues, CCUS technologies may still remain one of the least expensive abatement options currently available for many industries, such as the cement, steel, and chemicals industries [12].

RECENT GLOBAL ADVANCEMENTS

There are currently 135 CCS facilities worldwide under varying stages of development, with 71 added between January-September 2021, with 36 of the 71 additional added facilities located within the U.S. Of these 71 facilities, 38 are already operational [2]. Through the Climate Ambition Alliance, a collaboration between the UN Environment Programme and the Copenhagen Climate Centre, more than 700 cities worldwide have already pledged to reach net-zero emissions by 2050, and plan to implement CCS technologies as a part of their strategy. An additional ~20 M tonnes/year of CCS capacity is projected to be commercialized worldwide by 2025 [15]. The industries investing in these projects include electricity generation, natural gas processing, chemical production, and hydrogen production. The range of carbon utilization applications include the production of cement, iron, steel, hydrogen, ethanol, and fertilizer, as well as the use of traditional CCS technologies within natural gas and coal power generation plants.

It is projected a 100-fold increase in the number of CCS facilities currently operational today (27 worldwide) may be necessary by the year 2050 to meet emission reduction goals. As a result, the current operating capacity of 40 Mtpa of CCS worldwide may need to increase to 5,600 Mtpa by 2050 [2].

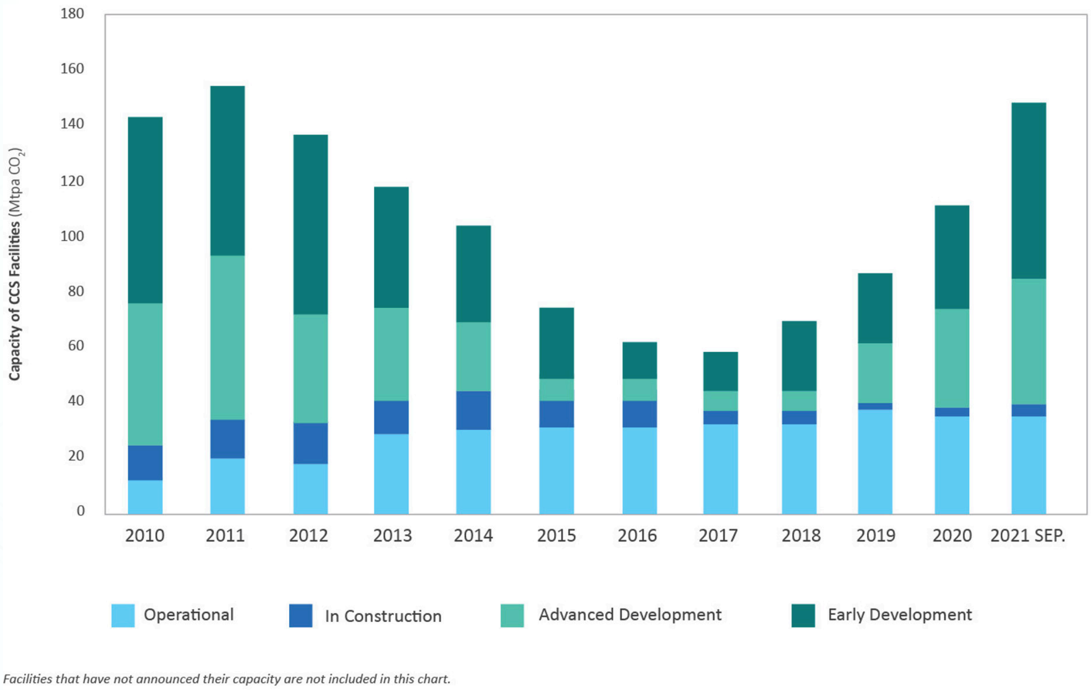

Figure 3: Trends in global CCS facility development, construction, and deployment over time. Source: [11].

U.S. PERSPECTIVE: 45Q TAX CREDIT AND OTHER POLICIES

An extension of the current 45Q tax credit within the United States could make CCS a more cost-effective technology [2]. The previous regulations under 45Q offer a tax credit that ranged from $12–$50 per metric ton of CO_2 that is captured and sequestered, although a recent proposal to Congress increased this to up to $85 per metric ton of CO_2 using traditional CCS capture methods, and up to $175 per ton of CO_2 for the use of DAC methods [16].

There are additional new policies which could encourage the deployment of CCS technologies. In November of 2021, President Biden signed the H.R.3684 Infrastructure Investment and Jobs Act (IIJA), which included Title III—Fuels and Technology Infrastructure Investments. Under this title, Subtitle A- Carbon capture, utilization, storage, and transportation infrastructure, authorizes several programs related to CCS [3]. In total, the infrastructure bill includes more than $62 billion to be allocated to the Department of Energy (DOE) over a five-year period, from FY 2022–2026. This includes $2.1 billion for the Carbon Dioxide Transportation Infrastructure Finance and Innovation Program (Sec.40304), and $2.5 billion for the Carbon Storage Validation and Testing Program (Sec.40305). The IIJA also establishes several new programs, including the Carbon Dioxide Transportation Infrastructure Finance and Innovation Program (CIFIA). The main goal of this program is to "provide low-interest loans for eligible CO_2 pipeline projects and grants for initial excess capacity on eligible new pipelines", of which $2.1 billion has been allocated for FY2022–FY2023. Additional new programs focus on funding commercial large-scale CCS projects and the development of regional DAC hubs [14].

FUTURE OUTLOOK AND ONGOING EPRI RESEARCH

Implementing CCUS technologies may enable net zero emissions and, collectively, may play an important role in keeping the world under the Paris Accord's two degrees Celsius temperature threshold. Both the IPCC's 1.5C Special report and their 6th Assessment Report highlight the contributions CCUS technologies may make. The 2018 1.5C Special Report states that reductions of CO_2 emissions from industry "...can be achieved through combinations of new and existing technologies and practices, including... carbon capture, utilization, and storage (CCUS). In industry, emissions reductions by energy and process efficiency by themselves are insufficient for limiting warming to 1.5°C with no or limited overshoot (high confidence)" [8].

In September of 2021, EPRI announced the CO2DA (**CO_2** Capture and Storage **D**eployment **A**cceleration) Initiative. This initiative is intended to "...provide an industry forum and collaborative technical approach to accelerate development of carbon capture, transport, and storage demonstration projects for power generation" for organizations who are interested in learning more about how CCS will play a key role in the decarbonization equation. One of the program's goals is that "Knowledge developed through CO2DA can support and inform an accelerated CCS pathway, investment decisions, and collaborative learnings driving down cost and increasing viability of overall CCS deployment" of both traditional CCS as well as carbon utilization across a variety of industries [13].

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