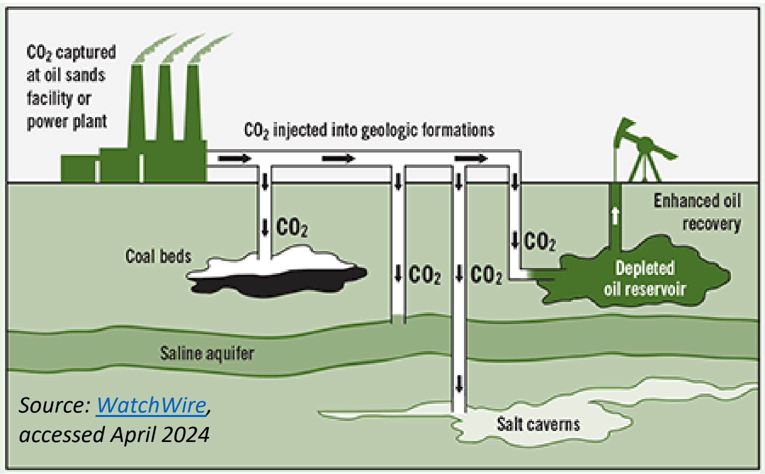
Can CCS Deliver? Exploring the Potential of Carbon Capture and Storage in Industry

Tyler Berard, Office of Industry and Competitiveness Analysis

As the world ramps up efforts to combat climate change, carbon capture and storage (CCS) has emerged as a potential tool for reducing carbon dioxide (CO_2) emissions in industrial processes, particularly from hard-to-abate industries such as cement, steel, and chemicals. However, high implementation costs, among other challenges, have limited its widespread adoption. This briefing discusses the current state of CCS deployment, recent industry developments, and the future outlook for this climate technology.

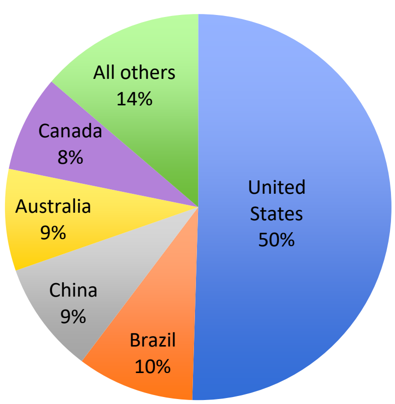
The CCS process consists of three main stages: capture, transport, and storage (figure 1). First, CO_2 is separated from other gases produced during industrial processes, such as those produced at power generation plants or steel mills.[1] Once the CO_2 is separated, it is then compressed and transported, most commonly via pipelines.[2] Finally, the CO_2 is injected into geologic formations (such as oil and gas reservoirs, deep saline formations, and shale basins) located deep underground for permanent storage.

Figure 1: Carbon Capture and Storage Process



Source: WatchWire, accessed April 2024

Figure 2: Shares of Global CO_2 Capture Capacity, 2022



Source: Statista / S&P Global, accessed April 2024

The United States is a Global Leader in CCS, But Adoption Across Industrial Applications Remains Limited

The United States leads the world in CCS deployment, accounting for roughly half of global capacity to capture CO_2 as of 2022, followed by Brazil, China, Australia, and Canada (figure 2). There are currently 15 operational CCS facilities in the United States with combined capacity to capture 22 million metric tons (mt) of CO_2 per year. These facilities are primarily concentrated in applications where CO_2 capture costs are relatively low (e.g., natural gas processing, ethanol production, and ammonia production).[3] Even at this level of deployment, U.S. capacity to capture CO_2 is equivalent to only 0.4 percent of the country's annual CO_2 emissions.[4]

[1] This is also referred to as point source capture because the process captures CO_2 from the point source of emission before it enters the atmosphere. In contrast, a separate process called direct air capture removes CO_2 from the atmosphere.

[2] Transportation by truck, rail, or ship may also be viable for transporting smaller volumes of CO_2 over short distances.

[3] Costs vary by industrial application and are influenced by factors such as the concentration of CO_2 in the gas stream, the amount of energy needed to compress the CO_2, and the scale of nearby transportation infrastructure.

[4] Combined global capacity to capture CO_2 accounts for only 0.1 percent of the world's annual CO_2 emissions.

The limited use of CCS is mainly due to high implementation costs, which vary depending on the industrial application. For applications in natural gas processing and the production of ethanol and ammonia, estimated costs range from $15 to $35 per metric ton of CO_2, whereas for power generation and the production of cement, iron, steel, and hydrogen the costs range from $50 to $120 per metric ton of CO_2.

Significant CO_2 Capture Capacity in the Development Pipeline, Backed by Recent Surge of Investments

The global market for CCS is projected to grow substantially as projects continue to develop and come online, driven by a recent surge of investments and incentive schemes from national governments. Since 2020, combined global capacity of CCS projects either in development or under construction has increased by over 50 percent year-over-year. CCS projects currently in the pipeline represent significant amounts of potential capacity additions: 32 million mt for projects under construction, 144 million mt for projects in the advanced development stage, and 135 million mt for projects in the early development stage.[5]

In the United States, the Infrastructure Investment and Jobs Act (2021) included $8.2 billion in advance appropriations for CCS through 2026. Also, the Inflation Reduction Act (2022) increased the value for the existing 45Q tax credit from $50 to $85 per mt of CO_2 that is geologically sequestered and from $35 to $65 per mt of CO_2 that is stored through enhanced oil recovery. Since 2018, the European Union has dedicated €4 billion across industrial carbon management projects, including 21 commercial-scale CCS facilities. Governments in Australia, Canada, Norway, and the United Kingdom have also announced investments and incentives aimed at scaling up CCS in their respective countries.

Costs, Infrastructure Buildout, and Policy Support Will Determine the Future of CCS Deployment

Several factors will play a role in determing the realization of CCS projects that are currently in the development pipeline. As CCS technology matures, newer projects gain knowledge from previous experiences, and as economies of scale are achieved, costs for capturing CO_2 are expected to fall.[6] Sustained cost declines have the potential to make CCS an economically viable option for applications that were previously deemed too expensive, such as power generation and cement production.[7] Building out complementary transportation and storage networks, while adhering to safety and environmental regulations, will also be crucial in bringing CCS projects fully online. Finally, government policies that support decarbonization efforts will influence firms' investment decisions as they assess risks and market opportunities for future CCS projects.

Sources: Baylin-Stern and Berghout, "Is Carbon Capture Too Expensive?," February 17, 2021; Casey, "CCUS Market Outlook 2023," November 9, 2023; CBO, "Carbon Capture and Storage in the United States," December 2023; Center for Climate and Energy Solutions, "Carbon Capture," accessed January 2024; Cygan-Jones et al., "Governments in Race to Unlock Potential of CCS," August 20201; Douglas, "Why Carbon Capture is No Easy Solution," November 27, 2023; European Commission, "Industrial Carbon Management," February 13, 2024; GAO, "Status, Challenges, and Policy Options for Carbon Capture," September 29, 2022; Global CCS Institute, "What is Carbon Capture and Storage?," accessed January 2024; Kearns et al., "Technology Readiness and Costs of CCS," March 2021; Lawson, "Carbon Capture Versus Direct Air Capture," November 16, 2021; and Mistry et al., "Two Paths to U.S. Competitiveness in Clean Technologies," March 2023.

[5] These figures include capacity from direct air capture projects.

[6] A recent example suggests this may already be occurring: CO_2 capture costs at a U.S. CCS facility operating at a power plant were estimated to be 35 percent lower than those for a similar Canadian CCS facility that came online just a few years prior.

[7] Reductions in CO_2 capture costs will have major implications for future CCS deployment, as these costs represent roughly three-fourths of total CCS costs, with the balance accounted for by transportation and storage costs.