RESOURCES for the FUTURE

Carbon Capture and Storage 101

Explainer by **Vincent Gonzales**, **Alan Krupnick**, and **Lauren Dunlap** — May 2020

1. Introduction

Carbon capture and sequestration/storage (CCS) is the process of capturing carbon dioxide (CO_2) formed during power generation and industrial processes and storing it so that it is not emitted into the atmosphere. CCS technologies have significant potential to reduce CO_2 emissions in energy systems. Facilities with CCS can capture almost all of the CO_2 they produce (some currently capture **90** or even **100 percent**). This explainer provides an overview of CCS technology, including how it works, where it is currently used in the United States, barriers to more widespread use, and policies that may affect its development and deployment. It also includes a list of additional resources for further reading.

Carbon Capture and Utilization

In some cases, captured CO_2 can be used to produce manufactured goods and in industrial and other processes, rather than being stored underground. Such utilization leads to the acronym **CCUS** (carbon capture, utilization, and storage). Different CO_2 uses **lead to different levels of emissions reductions**, depending on whether the CO_2 is permanently stored and whether its use displaces the use of fossil-fuel products or CO_2 produced in another way. One of the primary uses of CO_2 is for **enhanced oil recovery** (EOR), a method of oil extraction that uses CO_2 and water to drive oil up the well, improving oil recovery and sequestering the CO_2 underground. Selling CO_2 for EOR and other uses can provide revenue to CCS facilities, incentivizing further implementation of CCS technologies.

2. The State of CCS

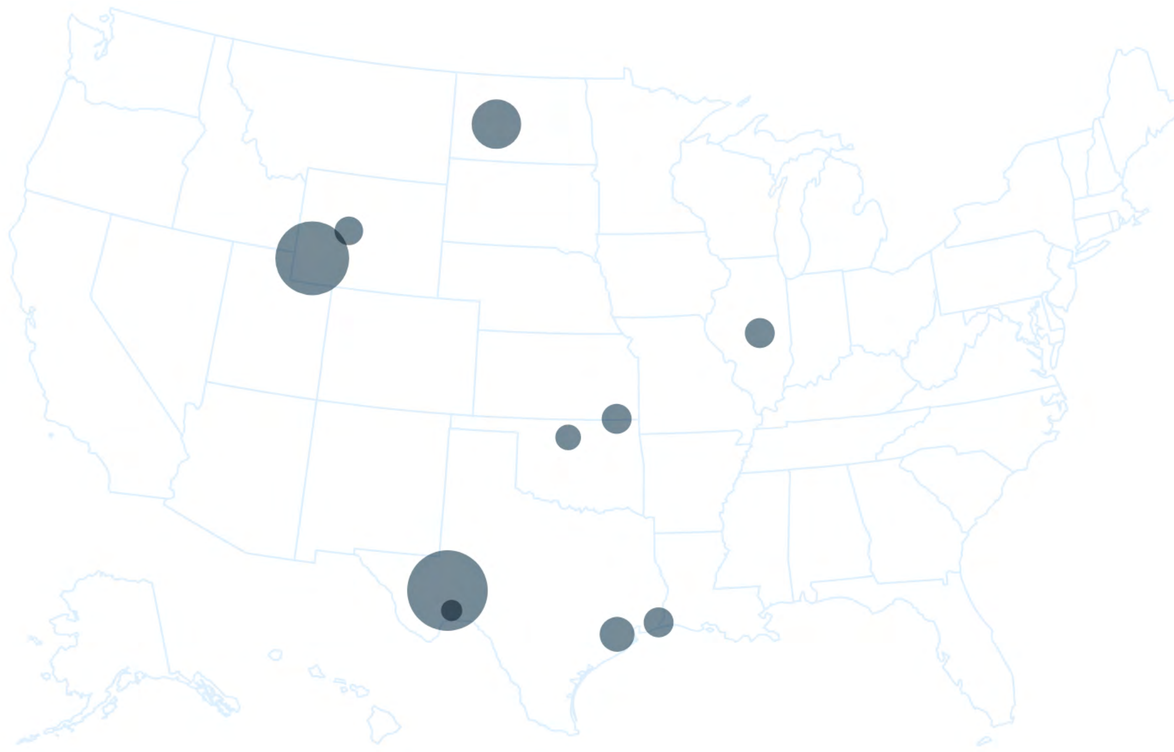
According to the **Global CCS Institute's 2019 Status Report**, 40 million metric tons of CO_2 from plants currently in operation or construction are captured and stored each year (for context, the United States alone emitted **over 5 billion metric tons** of CO_2 in 2018). Globally, there are 51 large-scale CCS facilities in operation or under construction. In the United States alone, there are 10 large-scale operational facilities, as shown in the map below. (The Global CCS Institute **defines** "large-scale facilities" as power plants capturing at least 800,000 metric tons of CO_2 annually and other industrial facilities capturing at least 400,000 metric tons of CO_2 annually.)

3. How CCS Works

Deploying CCS at a power plant or industrial facility generally entails **three** major steps: capture, transportation, and storage.

Several different technologies can be used to **capture** CO_2 at the **source** (the facility emitting CO_2). They fall into three categories: **post-combustion carbon capture** (the primary method used in existing power plants), **pre-combustion carbon capture** (largely used in industrial processes), and **oxy-fuel combustion systems**. For **post-combustion** carbon capture, CO_2 is separated from the exhaust of a combustion process. There

Figure 1. Large-Scale, Operational CCS Facilities in the United States



Source:: **Global CSS Institute**

are commercially available **pre-combustion** capture technologies used by industrial facilities; however, for power plants, pre-combustion capture is still in early stages. This technology involves gasifying fuel and separating out the CO_2. It may be less costly than other options; however, it can only be built into new facilities—to retrofit an existing facility for pre-combustion capture would be prohibitively costly. For **oxy-fuel combustion**, fuel is burned in a nearly pure-oxygen environment, rather than regular air, which results in a more concentrated stream of CO_2 emissions, which is easier to capture.

Once the CO_2 is captured, it is compressed into a fluid and **transported** to an appropriate **storage site**, usually by pipelines and/or ships and occasionally by trains or other vehicles.

Finally, in the third step, the CO_2 is injected into deep, underground geological formations, where it is **stored** long term, rather than being released into the atmosphere. **Storage sites** used for CO_2 include former oil and gas reservoirs, deep saline formations, and coal beds.

4. Barriers to Deployment

4.1. Cost of Implementation

One of the most significant barriers to widespread deployment of CCS technologies is the high cost of the technologies. Although cost estimates **vary widely**, the greatest costs are typically associated with the equipment and energy needed for the capture and compression phases. Capturing the CO_2 can **decrease plants' efficiency and increase their water use**, and the additional costs posed by these and other factors can ultimately render a CCS project financially nonviable. (Increased water use may also **pose problems** for plants that already face water scarcity.) Additionally, since CCS deployment is in its early stages, financial returns on a CCS project are riskier than normal operations. Consequently, investors impose higher risk premiums (the minimum amount of expected return required to attract investment), which further increases the private cost of the necessary capital. Mitigating risk for investors is vital for incentivizing investment and development of CCS. In order to realize full-scale deployment, additional research and development is required to optimize technology design and integration. Presently, the Department of Energy's **Carbon Capture Program** is exploring these issues.

4.2. Transportation Challenges

In addition to high costs of capture technology, there are also challenges associated with transporting CO_2 once it is captured. Transportation is **costly**: significant energy is required to compress CO_2 and maintain high pressure throughout pipelines, and the pipelines themselves are expensive. In order to safely carry the condensed, highly pressurized CO_2, pipelines must be **specially designed**: existing oil and gas pipelines cannot be used. Impurities in the CO_2 stream (including water) can cause damage to pipelines and lead to **dangerous leaks** and explosions as the compressed fluid rapidly expands to a gas. Finally, each source of CO_2 must be connected to an appropriate storage site via pipeline, which can make CCS more difficult and expensive to implement in areas without geological formations that are appropriate to use for storage.

4.3. Storage Considerations

The availability of geologic storage is generally not considered a barrier to widespread CCS deployment—at least not in the short to medium term. Indeed, there is probably **plenty of storage** worldwide for at least the next century, including specifically **in the United States**. While **some researchers** have expressed concerns about the long-term ability of storage sites to sequester carbon without significant leakage, a 2018 IPCC report **concludes** that "current evaluation has identified a number of processes that alone or in combination can result in very long-term storage" (pg. 245). There is also **some potential** for seismic activity caused by underground injection of CO_2; researchers continue to look at ways to minimize this risk, including considering above-ground **carbon dioxide mineralization** as an alternative to underground storage.

4.4. Uncertain Public Support

Finally, public support is **increasingly recognized** as critical to the widespread implementation of CCS. However, it is not well known how the public currently perceives the technology. Several **considerations** play a role in public opinion about CCS: acceptance of fossil fuels (as CCS may be viewed as prolonging the role of fossil fuels in the economy); acceptance of pipeline construction; perceived safety of transportation and storage of CO_2; perceived effectiveness of CCS; the extent to which other climate solutions are implemented in addition to CCS; and several other considerations that can shape an individual's view of CCS and, therefore, overarching public opinion. Further research is needed to better understand how the public thinks about and would react to substantial deployment of CCS.

4.5. Policies Related to CCS

As highlighted in the Intergovernmental Panel on Climate Change's **Special Report on Carbon Dioxide Capture and Storage**, in order to accelerate CCS development, policies that increase demand and reduce the costs will be needed. **Several** different types of policies have the potential to bring down the costs of CCS and encourage research, development, and deployment, including carbon pricing policies, public investment and subsidies, and clean energy standards that credit companies generating electricity or other energy sources with CCS.

In the United States, multiple enacted policies aid and encourage the use of CCS technology. National tax credits for carbon sequestration are created through **Section 45Q** of the Internal Revenue Code. Adding to these national tax credits, several tax credit and other crediting mechanisms exist at the state level in **California**, **Texas**, **Louisiana**, **Montana**, and **North Dakota**.

In addition to these existing policies, several proposed policies could impact the rate of development for CCS, including the **Launching Energy Advancement and Development through Innovations for Natural Gas Act**, **Enhancing Fossil Fuel Energy Carbon Technology Act**, and the **Fossil Energy Research and Development Act of 2019**. These policies differ in several ways, including how they would incentivize CCS deployment.

Additional Resources

Background Material

- **Global CCS Institute | Understanding CCS**
- **National Energy Technology Laboratory | Carbon Storage FAQ**
- **ClearPath | "Carbon Capture 101"**

Status of CCS

- **IPCC | Special Report on CCS, 2018**
- **Global CCS Institute | 2019 Status Report**

More from RFF

- **Podcast | Going Deep on Carbon Capture, Utilization, and Storage (CCUS), with Julio Friedmann**
- **Blog | 45Q&A: A Series of Comments on the 45Q Tax Credit for Carbon Capture, Utilization, and Storage (CCUS)**
- **Issue Brief | Subsidizing Carbon Capture Utilization and Storage: Issues with 45Q**
- **Workshop | "The Future of Carbon Capture, Utilization, and Storage (CCUS): Status, Issues, Needs"**
- **Media Highlight | "This new 'battery' aims to spark a carbon capture revolution"**

Resources for the Future (RFF) is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. The views expressed here are those of the individual authors and may differ from those of other RFF experts, its officers, or its directors.

Vincent Gonzales is a research analyst at RFF.

Alan Krupnick is a senior fellow at Resources for the Future and an expert on the oil and gas sector, reducing greenhouse gas emissions from this and the industrial sectors, and cost-benefit analysis.

Lauren Dunlap is the communications specialist at RFF. She manages RFF publications and works on a variety of internal and external communications projects at RFF.