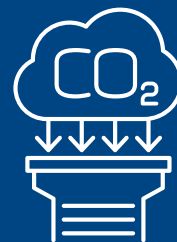


Can Carbon Capture and Storage (CCS) Help Decarbonize the Grid?



Carbon capture and storage (CCS) technologies remove carbon dioxide (CO₂) from industrial sources like power plants and oil refineries, to be stored or used. As electricity demand increases from factors including electrification and the proliferation of data centers, fossil fuel power plants with CCS are being considered as a potential source of “clean firm” low-emissions energy generation.

However, the high cost and questionable efficacy of CCS make it poorly suited to meet near-term energy demand and reduce pollution. There are only two operational CCS power plants in the world, and neither has achieved a high carbon capture rate. Most operational CCS projects are used for fossil fuel extraction, perpetuating reliance on polluting industries and negating any environmental benefits. Other clean firm energy sources, such as geothermal or long-duration energy storage, are likely to be more cost effective, safer, and faster to deploy.

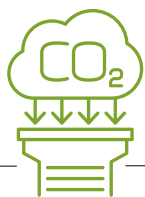
What is Carbon Capture and Storage?

CCS technologies remove CO₂ from emitting sources and then transport and either permanently store the captured carbon or use it for other purposes. There are two main forms of CCS:

- **Point-source capture** is the most common form of CCS. It targets CO₂ emissions from stationary sources such as power plants, oil refineries, and cement production facilities. The most common form of point-source capture is post-combustion capture, in which chemical solvents known as amines remove CO₂ from the exhaust flue of a combustion turbine.

What is “Clean Firm” Energy Generation?

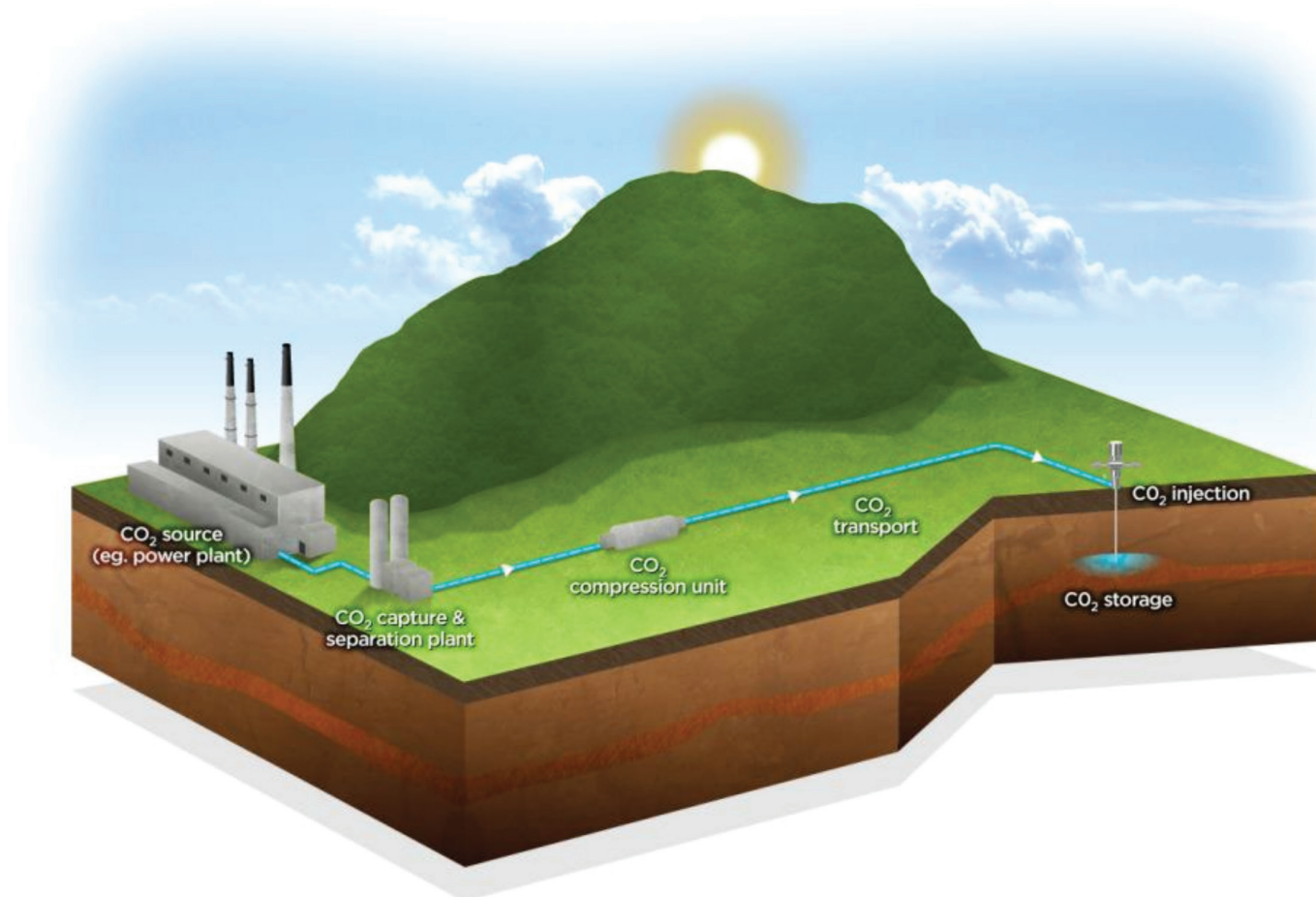
While definitions vary, “clean firm” generally refers to technologies that are (1) considered low- or zero-carbon (although the term is sometimes used to describe technologies that are not actually low carbon), (2) are always available to generate electricity on demand, and (3) can generate electricity for long periods of time. Clean firm technologies are a necessary complement to intermittent renewable energy resources such as wind and solar. Nuclear, geothermal, and long-duration energy storage are typically classified as clean firm.



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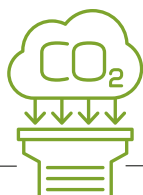
- **Direct air capture** (DAC) is a method of removing CO₂ from the atmosphere by passing air through chemicals or physical filters that bind with CO₂, then returning the air, now with less CO₂, to the atmosphere.

In both methods, the captured carbon is then transported to a storage location, usually an underground well. However, it is much more common for the carbon to be repurposed than permanently stored. This process is known as carbon capture, utilization, and storage (CCUS). Globally, **73 percent** of captured carbon from CCUS projects is reinjected into depleted oil or gas wells to extract additional fossil fuels in a process known as Enhanced Oil Recovery (EOR).



An illustration of a CCS network, from the point of capture to the storage facility.

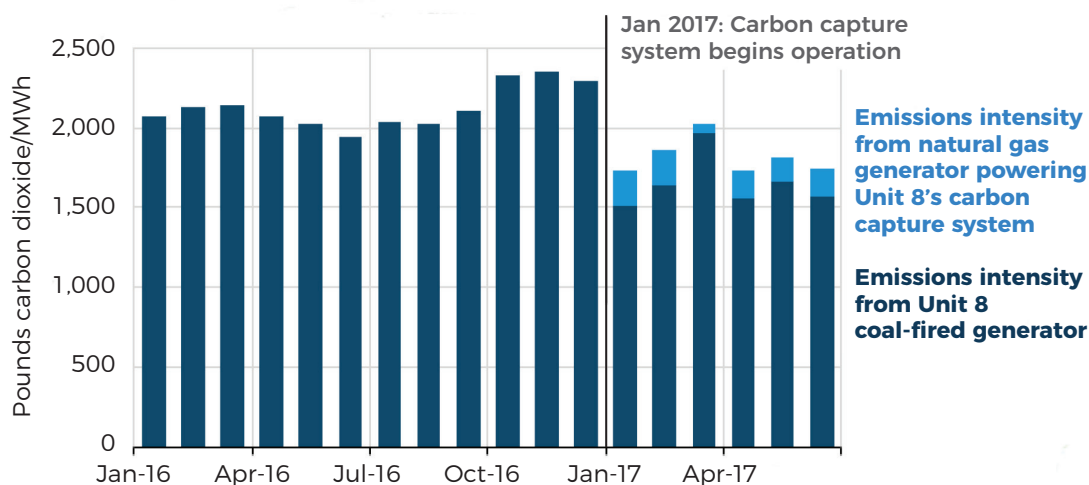
Source: U.S. Department of Energy.



Can Carbon Capture and Storage (CCS) Help Decarbonize the Grid?

CCS Has Consistently Failed to Significantly Reduce CO₂ Emissions

CCS for power generation has not been demonstrated at scale. Only two commercial CCS power plants are operating in the world, both coal plants: the **Boundary Dam coal plant** in Saskatchewan, Canada, and the **Petra Nova coal plant** in Houston, Texas. The 240-megawatt CCS system at Petra Nova was designed to capture 90 percent of the flue gas CO₂ emissions from a 654-megawatt coal-fired turbine at the site. During the three years it was operating as a demonstration project, the plant only achieved 90 percent capture when the turbine was running at 100 percent capacity, and only ever captured the emissions from the flue gas, not the total emissions from the unit. During all other periods, such as when the plant was ramping operations up or down, the CCS technology **failed to operate**. Because of this, the overall emissions reductions from the turbine (Unit 8) were only 33 percent. The Boundary Dam has similarly **never achieved** a sustained 90 percent capture rate. Over the course of four months, the CCS technology **was only available 67.6 percent of the time**. **No CCS project** has ever achieved its stated capture rate.

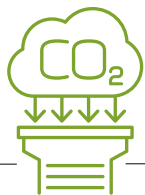


Carbon dioxide emission intensity at W.A. Parish Unit 8 (January 2016–June 2017).

Emissions reductions from Petra Nova's Unit 8 generator when paired with CCS. The 240 MW CCS system only reduced total emissions from the unit by 33 percent, despite claiming a 90 percent capture rate. The system also requires power from a dedicated natural gas generator on-site, which creates additional emissions.

Source: U.S. Energy Information Administration.

Once the chemical compounds capture the carbon, they must then be heated to over 120 degrees Fahrenheit to release the carbon, which must then be compressed for transport. These additional processes can consume **10 to 30 percent** of the power plant's energy, meaning that power plants with CCS must consume more fuel to generate the same amount of power as those without CCS. The



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increased natural gas needed to power the CCS equipment, as well as the upstream emissions, mean that CCS plants only capture a net of **10.5 percent** of carbon emissions over 20 years.

In addition to upstream emissions, CO₂ storage is prone to leakage, particularly when CO₂ is injected into an underground well. The risk of leakage increases over time as more CO₂ is injected and pressure builds in the well. Geological formations such as natural fissures or fault lines can also lead to inadvertent leakage. While strong oversight and monitoring can help mitigate leakage risk, there is not enough long-term data on carbon storage to support the long-term effectiveness of those measures.

CCS Increases Local Air Pollution

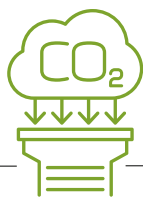
In addition to increased upstream emissions, CCS can increase local air pollutant emissions. Amines, the chemical solvents used in post-combustion capture, can degrade and turn into ammonia, a potent chemical with harmful effects on the human body when inhaled. In addition, the increased fuel that must be combusted to power the CCS equipment can lead to higher local air pollutant emissions, which can cause significant harm in nearby communities. **One study** found that retrofitting existing natural gas plants with CCS could increase premature mortality rates in nearby communities by at least 12 percent.

Transporting Carbon Can Lead to Dangerous Explosions

Even if carbon is effectively captured at the power plant, it must then be transported to a secure storage facility. This is typically done through dedicated carbon pipelines that move compressed CO₂ into an injection well thousands of feet underground. Transporting large quantities of liquid or gaseous CO₂ at high pressure can be extremely dangerous: even a minor leak can raise the concentration of CO₂ in the nearby atmosphere enough **to cause health problems**, particularly for more vulnerable populations such as children. CO₂ poisoning can also have lasting effects. Following a catastrophic CO₂ pipeline explosion in 2020, residents of Satartia, Mississippi, **continue to deal** with respiratory illnesses.

CCS Projects are Expensive

CCS projects are **50 percent more expensive** than renewable energy resources such as solar and wind. A single CCS project can require **over a billion dollars** in upfront investment because of the scale of the power plants and the infrastructure needed to manage the tons of CO₂ captured annually. If used for power generation, these costs will increase energy costs overall, contributing to rising utility bills.



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In addition to paying for CCS through their utility bills, households could end up subsidizing projects through their taxes. Because of their high cost, many CCS projects are financially dependent on [the federal 45Q tax credit](#), which incentivizes carbon captured for both geologic storage and for EOR. Under current rules for the credit, taxpayers could end up paying [hundreds of billions of dollars](#) for CCS projects.

The Future of CCS

Although CCS remains expensive, ineffective, polluting, and dangerous to public health, there continues to be interest in it as a decarbonization tool. In 2024, the U.S. Environmental Protection Agency (EPA) proposed new greenhouse gas emissions standards for power plants, which, if enacted, would have required many new and existing power plants to implement CCS or to co-fire a blend of 30 percent hydrogen. Under the Trump Administration, the EPA has since proposed to rescind all greenhouse gas emissions standards for power plants.

Regulations requiring CCS for power plants remain in limbo. [Utilities, state energy offices](#), and [data center developers](#) exploring power plants with CCS as a source of clean firm power must consider the cost, efficacy, and environmental impacts of the technology. Truly zero-carbon, firm energy resources, such as geothermal and long-duration energy storage, are safer, more cost effective, and more reliable solutions.



Clean Energy Group (CEG) is a national nonprofit organization working on innovative technical, economic, and policy solutions to accelerate the equitable deployment of clean energy technologies. By serving as a trusted partner for communities, advocates, and policymakers working at the forefront of the energy transition, CEG bridges critical gaps in the clean energy space through expert technical assistance, responsive guidance, and independent analysis. Learn more at www.cleanegroup.org.