



Climate Solutions » Technology Solutions

SHARE

# Carbon Capture

## At-a-glance

- Carbon capture, use, and storage technologies can capture more than 90 percent of carbon dioxide (CO<sub>2</sub>) emissions from power plants and industrial facilities.
- Captured carbon dioxide can be put to productive use in enhanced oil recovery and the manufacture of fuels, building materials, and more, or be stored in underground geologic formations.
- Twenty-six commercial-scale carbon capture projects are operating around the world with 21 more in early development and 13 in advanced development reaching front end engineering design (FEED).
- Carbon capture can achieve 14 percent of the global greenhouse gas emissions reductions needed by 2050 and is viewed as the only practical way to achieve deep decarbonization in the industrial sector.

## Overview

Even as nations diversify their energy portfolios, fossil fuels are expected to meet a majority of the world's energy demand for several decades. Accelerating deployment of carbon capture technology is essential to reduce emissions from these power plants, and from industrial plants like cement and steel manufacturing.

More than half of the models cited in the [Intergovernmental Panel on Climate Change's Fifth Assessment Report](#) required carbon capture for a goal of staying within 2 degrees Celsius of warming from pre-industrial days. For models without carbon capture, emissions

reduction costs rose 138 percent.

For nearly a half century, in a practice called enhanced oil recovery (EOR), carbon dioxide has been used to extract additional oil from developed oil fields in the United States. U.S. companies are also investing in new technologies to re-use captured carbon emissions in innovative ways, including jet fuel and automobile seats. Spurred by the [NRG COSIA Carbon XPRIZE](#), researchers are exploring even more uses, such as transforming carbon emissions into algae biofuels and building materials.

As many experts see hydrogen as a clean fuel of the future and expect it to play a major role in decarbonizing the industrial sector, a process such as natural gas reforming with carbon capture technology presents itself as the lowest cost option for producing clean hydrogen. This process produces “blue hydrogen” by reforming natural gas into hydrogen and carbon dioxide; the carbon dioxide by-product will be captured, transported, and stored in deep geologic formations. The addition of carbon capture makes the hydrogen production process nearly emissions free, when clean electricity is used to power the carbon capture facility.

## Policy Support for Carbon Capture

There is strong bipartisan support to accelerate carbon capture deployment. In February 2018, Congress extended and expanded key financial incentives for investment in [several advanced low-carbon technologies](#). The two-year budget package included the [FUTURE Act](#), sponsored by Senators Heidi Heitkamp (D-N.D.), Shelley Moore Capito (R-W.Va.), Sheldon Whitehouse (D-R.I.), and John Barrasso (R-Wyo.). The legislation reforms and extends a federal tax credit to boost carbon capture, known as [Section 45Q](#). The FUTURE Act also allows for the first time use of the tax credit for capture of carbon monoxide from industrial facilities like steel mills, [direct air capture](#) (DAC) of carbon dioxide from the atmosphere, and for the [conversion of captured carbon into useful products](#).

In 2018, the California’s Low Carbon Fuel Standard (LCFS) was amended to enable carbon capture and storage projects that are associated with the production of transport fuels sold in California to generate LCFS credits. It also enabled DAC projects to generate credits regardless of their location even if they do not have a fuel component as the only exception to the rule. These changes came into effect in January 2019.

In December 2020, Congress enacted a two-year extension of the 45Q tax credit as a part of the [Consolidated Appropriations Act, 2021](#) to require qualified facilities to commence construction by December 31, 2025.

C2ES and the Great Plains Institute co-convene a [diverse coalition](#) of industry, labor, and environmental groups that support expanding deployment of carbon capture. Other supporters of incentivizing carbon capture include the Western Governors Association, Southern States Energy Board, and National Association of Regulatory Utility Commissioner

## Carbon Capture in Action

As of 2020, at least 26 commercial-scale carbon capture projects are operating around the world with 21 more in early development and 13 in advanced development reaching front end engineering design (FEED). Industrial processes where large-scale carbon capture has

been demonstrated and is in commercial operation include coal gasification, ethanol production, fertilizer production, natural gas processing, refinery hydrogen production and, most recently, coal-fired power generation.

## Carbon Capture Milestones

1972: Terrell gas processing plant in Texas. A natural gas processing facility (along with several others) began supplying carbon dioxide in West Texas through the first large-scale, long-distance carbon dioxide pipeline to an oilfield.

1982: Koch Nitrogen Company Enid Fertilizer plant in Oklahoma. This fertilizer production plant supplies carbon dioxide to oil fields in southern Oklahoma.

1986: Exxon Shute Creek Gas Processing Facility in Wyoming. This natural gas processing plant serves ExxonMobil, Chevron, and Anadarko Petroleum carbon dioxide pipeline systems to oil fields in Wyoming and Colorado and is the largest commercial carbon capture facility in the world at 7 million tons of capacity annually.

1996: Sleipner Carbon Dioxide Storage Facility offshore of Norway. This project captures carbon dioxide from gas development for storage in an offshore sandstone reservoir. It was the world's first geologic storage project. Roughly 0.85 million tonnes of CO<sub>2</sub> is injected annually for a cumulative total of over 16.5 million tonnes as of January 2017.

2000: Dakota Gasification's Great Plains Synfuels Plant in North Dakota. This coal gasification plant produces synthetic natural gas, fertilizer, and other byproducts. It has supplied over 30 million tons of carbon dioxide to Cenovus and Apache-operated EOR fields in southern Saskatchewan as of 2015.

2003: Core Energy/South Chester Gas Processing Plant in Michigan. Carbon dioxide is captured by Core Energy from natural gas processing for EOR in northern Michigan with over 2 million MT captured to date.

2008: Snøhvit Carbon Dioxide Storage offshore of Norway. Carbon dioxide is captured from an LNG facility on an island in the Barents Sea. The captured carbon dioxide is stored in an offshore subsurface reservoir. To date, more than 4 million tons of carbon dioxide have been stored.

2009: Chaparral/Conestoga Energy Partners' Arkalon Bioethanol plant in Kansas. The first ethanol plant to deploy carbon capture, it supplies 170,000 tons of carbon dioxide per year to Chaparral Energy, which uses it for EOR in Texas oil fields.

2010: Occidental Petroleum's Century Plant in Texas. The carbon dioxide stream from this natural gas processing facility is compressed and transported for use in the Permian Basin.

2012: Air Products Port Arthur Steam Methane Reformer Project in Texas. Two hydrogen production units at this refinery produce a million tons of carbon dioxide annually for use in Texas oilfields.

2012: Conestoga Energy Partners/PetroSantander Bonanza Bioethanol plant in Kansas. This ethanol plant captures and supplies roughly 100,000 tons of carbon dioxide per year to a Kansas EOR field.

2013: ConocoPhillips Lost Cabin plant in Wyoming. The carbon dioxide stream from this natural gas processing facility is compressed and transported to the Bell Creek oil field in Montana via Denbury Resources' Greencore pipeline.

2013: Chaparral/CVR Energy Coffeyville Gasification Plant in Kansas. The carbon dioxide stream (approximately 850,000 tons per year) from a nitrogen fertilizer production process based on gasification of petroleum coke is captured, compressed and transported to a Chaparral-operated oil field in northeastern Oklahoma.

2013: Antrim Gas Plant in Michigan. Carbon dioxide from a gas processing plant owned by DTE Energy is captured at a rate of approximately 1,000 tons per day and injected into a nearby oil field operated by Core Energy in the Northern Reef Trend of the Michigan Basin.

2013: Petrobras Santos Basin Pre-Salt Oil Field CCS offshore of Brazil. This project involves capturing carbon dioxide from natural gas processing for use in enhanced oil recovery in the Lula and Sapinhoá oil fields.

2014: SaskPower Boundary Dam project in Saskatchewan, Canada. SaskPower completed the first commercial-scale retrofit of an existing coal-fired power plant with carbon capture technology, selling carbon dioxide locally for EOR in Saskatchewan.

2015: Shell Quest project in Alberta, Canada. Shell began operations on a bitumen upgrader complex that captures approximately one million tons of carbon dioxide annually from hydrogen production units and injects it into a deep saline formation.

2015: Uthmaniyah CO<sub>2</sub>-EOR Demonstration in Saudi Arabia. This project captures carbon dioxide from the Hawiyah natural gas liquids recovery plant. The captured carbon dioxide is used for enhanced oil recovery in the Ghawar oil field.

2016: Abu Dhabi CCS Project Phase 1: Emirates Steel Industries. Carbon capture technology was deployed for the first time on an operating iron and steel plant. The captured carbon dioxide is used for enhanced oil recovery by the Abu Dhabi National Oil Company.

2017: NRG Petra Nova project in Texas. NRG completed on time and on budget a project to capture 90 percent of the carbon dioxide from a 240 MW slipstream of flue gas of its existing WA Parish plant, or roughly 1.6 million tons of carbon dioxide per year. The carbon dioxide is transported to an oil field nearby.

2017: ADM Illinois Industrial Carbon Capture & Storage Project. Archer Daniels Midland began capturing carbon dioxide from an ethanol production facility and sequestering it in a nearby deep saline formation. The project can capture up to 1.1 million tons of carbon dioxide per year.

2020: Boundary Dam 3 facility in Saskatchewan, Canada surpassed over 4 million tons of carbon dioxide captured and stored.

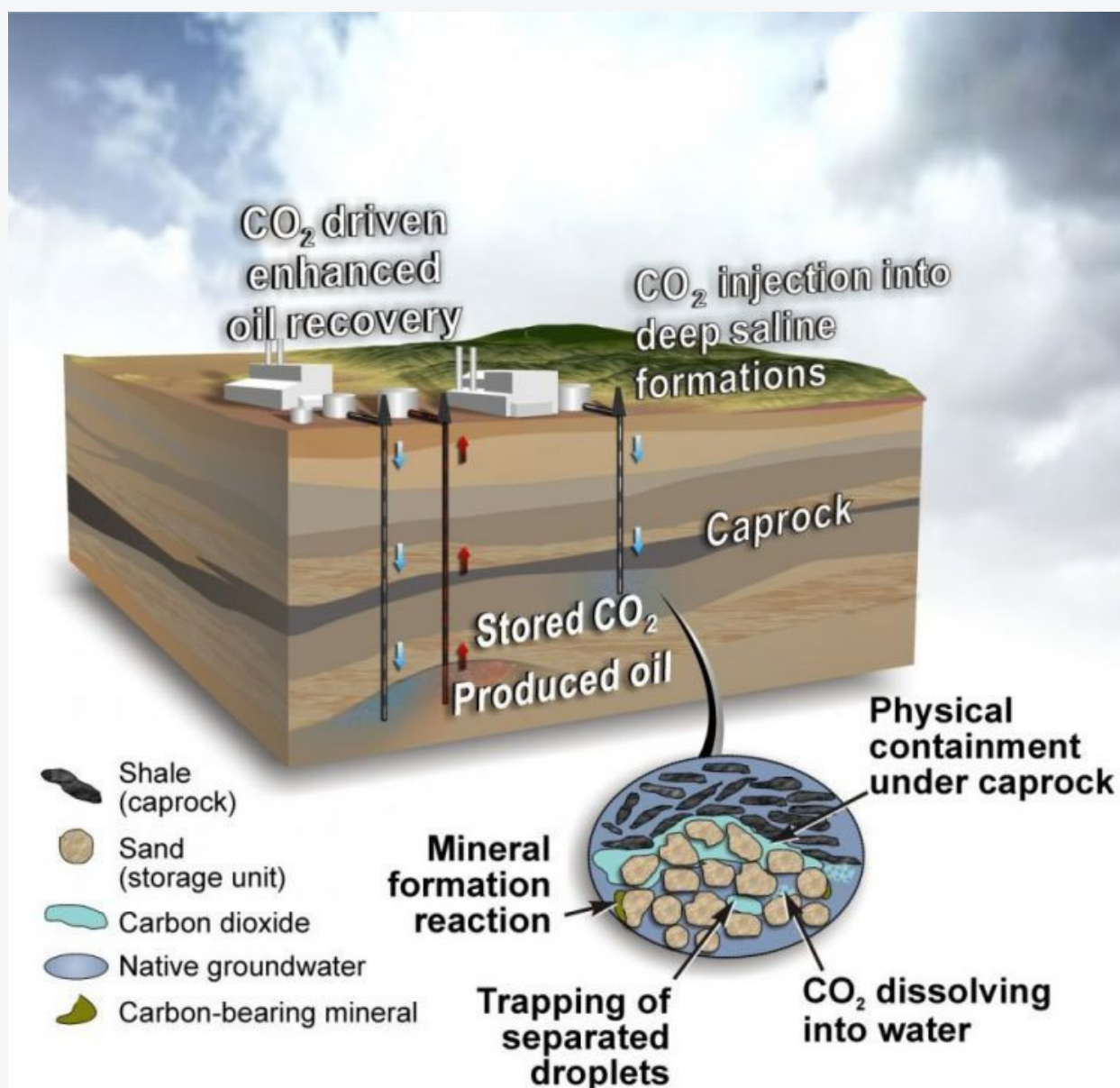
2020: Shell Quest project in Alberta, Canada which captures carbon dioxide from a hydrogen production unit at the Scotford refinery

surpassed 5 million tons of carbon dioxide stored.

2020: NRG Petra Nova Project in Texas was idled due to the collapse of West Texas crude oil prices early in the COVID-19 pandemic.

2020: Hydrogen to Humber Saltend (H2H Saltend) project in the UK. Norwegian energy company Equinor announced a project to produce zero-emission hydrogen from natural gas in combination with carbon capture and storage technology to provide clean energy to the Humber region, the UK'S largest industrial cluster.

## How Carbon Capture Works



## SOURCE

California Air Resources Board

## How Carbon Capture Works

Carbon capture technology has been deployed at several industrial projects in North America dating back to the 1970s but its application to power generation is relatively recent.

### Carbon Capture

Early commercial applications of carbon capture focused on certain industrial processes that remove carbon dioxide in concentrated streams as part of normal operations. For other industrial processes and electricity generation, current systems must be redesigned to capture and concentrate carbon dioxide, usually using one of these methods:

- **Pre-Combustion Carbon Capture:** Fuel is gasified (rather than combusted) to produce a synthesis gas, or syngas, consisting mainly of carbon monoxide (CO) and hydrogen (H<sub>2</sub>). A subsequent shift reaction converts the CO to CO<sub>2</sub>, and then a physical solvent typically separates the CO<sub>2</sub> from H<sub>2</sub>. For power generation, pre-combustion carbon capture can be combined with an integrated gasification combined cycle (IGCC) power plant that burns the H<sub>2</sub> in a combustion turbine and uses the exhaust heat to power a steam turbine.
- **Post-Combustion Carbon Capture:** Post-combustion capture typically uses chemical solvents to separate carbon dioxide out of the flue gas from fossil fuel combustion. Retrofits of existing power plants for carbon capture are likely to use this method.
- **Oxyfuel Carbon Capture:** Oxyfuel capture requires fossil fuel combustion in pure oxygen (rather than air) so that the exhaust gas is carbon-dioxide-rich, which facilitates capture.

### Transportation

Once captured, carbon dioxide must be transported from its source to a storage site. There are [more than 4,500 miles](#) of pipelines for transporting carbon dioxide in the United States for use in enhanced oil recovery, but more will be needed.

### Storage

Carbon dioxide can be injected into geological formations and stored deep underground. U.S. geological formations could store carbon dioxide emissions from centuries of continued fossil fuel use. Options for carbon dioxide geologic storage include:

- Oil and Gas Reservoirs (Enhanced Oil Recovery with Carbon Dioxide, Carbon Dioxide -EOR). Oil and gas reservoirs offer geologic storage potential as well as economic opportunity by injecting carbon dioxide to extract additional oil from developed sites. Oil and gas reservoirs are thought to be suitable candidates for the geologic storage of carbon dioxide given that they have held oil and gas resources in place for millions of years, and previous fossil fuel exploration has yielded valuable data on subsurface areas that could help to ensure permanent CO<sub>2</sub>geologic storage. carbon dioxide-EOR operations have been operating in West Texas for over 30 years. Moreover, revenue from selling captured carbon dioxide to EOR operators could help defray the cost of capture technology at power plants and industrial facilities.
- Deep Saline Formations. These porous rock formations infused with brine are located across the United States but have not been examined as extensively as oil and gas reservoirs.
- Coal Beds. Coal beds that are too deep or too thin to be economically mined could offer carbon dioxide storage potential. Captured carbon dioxide can also be used in enhanced coalbed methane recovery (ECBM) to extract methane gas.
- Basalt formations and shale basins. These are also considered potential future geologic storage locations.



### Estimates of CO<sub>2</sub> Stationary Source Emissions and Estimates of CO<sub>2</sub> Storage Resources for Geologic Storage Sites

RCSP or Geographic Region	CO <sub>2</sub> Stationary Sources		CO <sub>2</sub> Storage Resource Estimates (billion metric tons of CO <sub>2</sub> )								
	CO <sub>2</sub> Emissions (million metric tons per year)	Number of Sources	Saline Formations			Oil and Gas Reservoirs			Unmineable Coal Areas		
			Low	Med***	High	Low	Med***	High	Low	Med***	High
BSCSP	115	301	211	805	2,152	<1	<1	1	<1	<1	<1
MGSC	267	380	41	163	421	<1	<1	<1	2	3	3
MRCSP	604	1,308	108	122	143	9	14	26	<1	<1	<1
PCOR*	522	946	305	583	1,012	2	4	9	7	7	7
SECARB	1,022	1,857	1,376	5,257	14,089	27	34	41	33	51	75
SWP	326	779	256	1,000	2,693	144	147	148	<1	1	2
WESTCARB*	162	555	82	398	1,124	4	5	7	11	17	25
Non-RCSP**	53	232	--	--	--	--	--	--	--	--	--
<b>Total</b>	<b>3,071</b>	<b>6,358</b>	<b>2,379</b>	<b>8,328</b>	<b>21,633</b>	<b>186</b>	<b>205</b>	<b>232</b>	<b>54</b>	<b>80</b>	<b>113</b>

Source: U.S. Carbon Storage Atlas –Fifth Edition (Atlas V); data current as of November 2014  
 \* Totals include Canadian sources identified by the RCSP  
 \*\* As of November 2014, "U.S. Non-RCSP" includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and Puerto Rico  
 \*\*\* Medium = p50



SOURCE

U.S. Department of Energy

Carbon Storage Regulation

U.S. federal and state regulations cover carbon dioxide storage site selection and injection. In addition, systems for measurement, monitoring, verification, accounting, and risk assessment can minimize or mitigate the potential of stored carbon dioxide to pose risks to humans and the environment.

Carbon dioxide injection in EOR wells is commercially proven and has a history of safely storing carbon dioxide underground. For



example, research by the [University of Texas Bureau of Economic Geology](#) found no evidence of leakage from the SACROC oil field where carbon dioxide-EOR has been performed since the 1970s.

In the United States, the Safe Drinking Water Act and the U.S. Environmental Protection Agency's (EPA) Underground Injection Control Program impose safety requirements on carbon dioxide injection. In addition, the Clean Air Act and the EPA's Greenhouse Gas Emissions Program require project operators to report data on carbon dioxide injections and submit monitoring, reporting, and verification (MRV) plans if carbon dioxide is injected for geologic storage. In addition, the Underground Injection Control Program requires previous seismic history to be considered when selecting geologic carbon dioxide sequestration sites. The risk of small earthquakes causing carbon dioxide leakage to the surface is mitigated by multiple layers of rock that prevent carbon dioxide from reaching the surface even if it migrates from an injection zone.

U.S. state regulations can include additional requirements. See our state policy maps on:

- [Rules for Carbon Dioxide Transport and Storage](#)
- [Regulations and Rules for CCS and Carbon Dioxide-EOR](#)
- [Energy Financial Incentives for CCS](#)

## Requirements for Long Term Carbon Dioxide (CO<sub>2</sub>) Storage

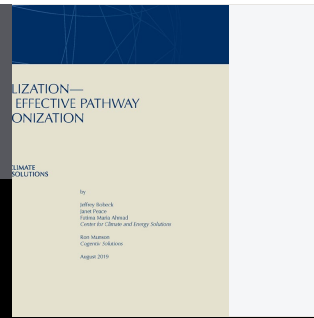
### □ Related Content

BLOG  
POST

Putting  
the "U" in

LIVE EVENT

Opportunities in  
Carbon



CCUS

[VIEW](#)

Judith Greenwald

May 3, 2012

[VIEW](#)

Utilization: A Vital Pathway to Decarbonization

September 5, 2019

10:00 am – 12:00 pm



SPEECH

[VIEW](#)

Testimony of Jeffrey Bobeck before the U.S. House Subcommittee on Energy

June 19, 2019



PUBLICATION

Strengthening International Collaboration on Carbon Capture Use and Storage

PUBLICATION

[Other Resources](#)

[Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects](#)

Follow



Sign up for updates

Donate to C2ES



CENTER FOR CLIMATE AND ENERGY SOLUTIONS

[POLICY HUB](#) [CLIMATE SOLUTIONS](#) [CLIMATE BASICS](#) [OUR WORK](#) [ABOUT](#) [LIBRARY](#)

DESIGNED BY  **Habitat Seven**