Institute for Energy Economics and Financial Analysis

Carbon Capture: CCS | CCUS | CCU

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Carbon Capture and Storage

Carbon capture and storage (CCS) is a 50-year-old technology with variable results in capturing and storing carbon dioxide. The majority of projects have used CCS for enhanced oil recovery (EOR), producing more oil and gas and more emissions.

Emissions

85% of emissions come from **burning** gas.

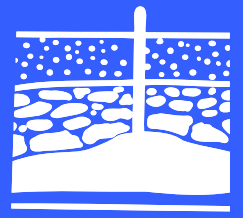
CCS/CCUS applies to gas **production** which creates around **15%** of emissions.

Snapshot of Carbon Capture

300 million tonnes of carbon has been captured throughout the technology's 50-year history.

Approximately three quarters of all carbon capture projects are used for enhanced oil recovery.

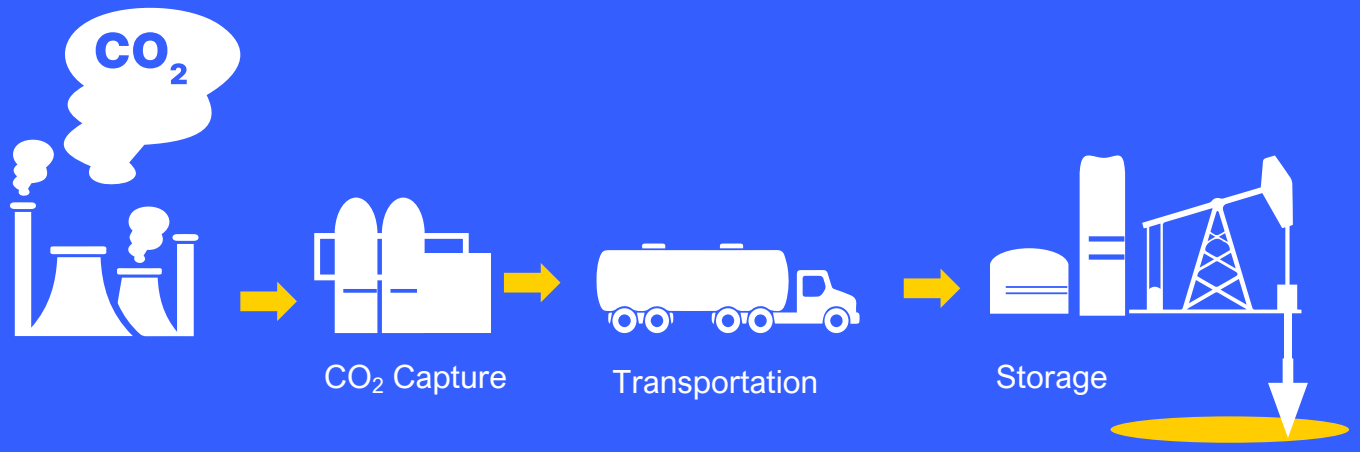
CCUS facilities capture roughly 28 million tonnes of CO_2 annually. The CCS/CCUS industry in total captures 39 million tonnes.



Only ~10–20% of carbon capture projects have stored carbon in dedicated geological structures, without using it for enhanced oil recovery.

Carbon Capture and Storage (CCS)

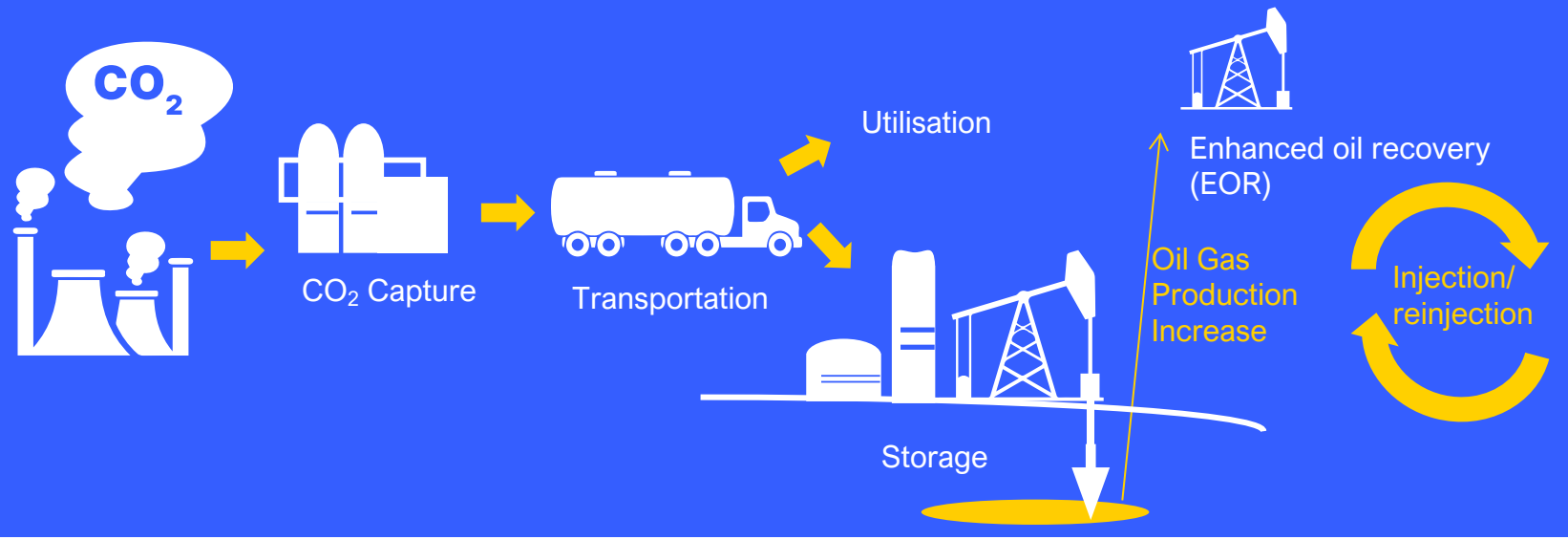
Carbon Capture and Storage (CCS): Carbon is captured from a stationary source, such as power generation plants, and is transported to sites and stored in saline aquifers or other underground deposits – and is not used for enhanced oil recovery (EOR).



=27%
of the total current capture capacity

Carbon Capture Utilisation and Storage (CCUS)

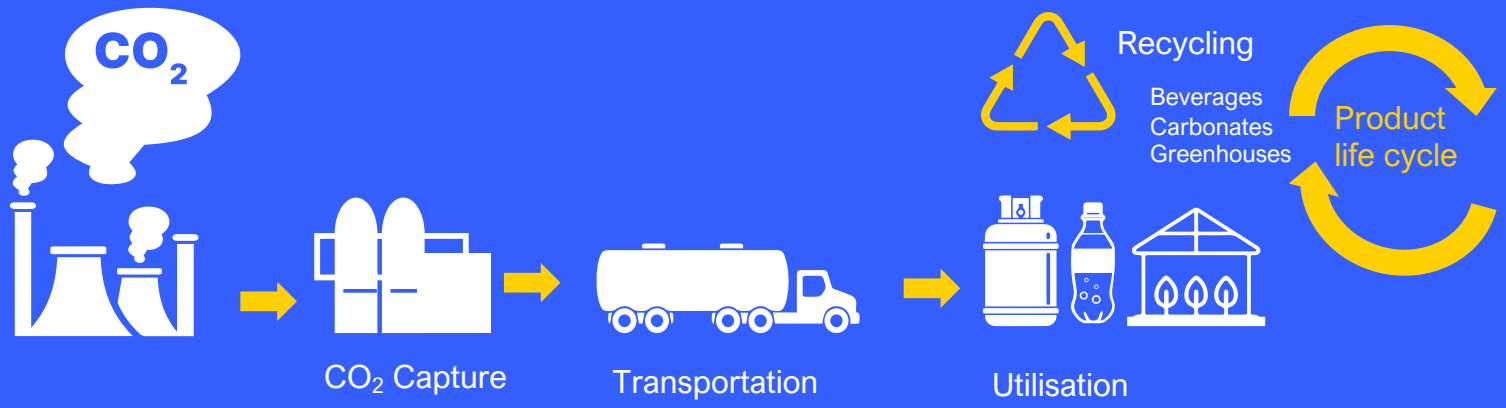
Carbon Capture Utilisation and Storage (CCUS): Captured carbon is sold and utilised for enhanced oil recovery (EOR) – where it is pumped into depleted fields to push more oil and gas out of wells - and then stored underground. Selling captured CO2 enhances the economic viability of gas development projects. Enhancing oil production increases carbon emissions, negating CO2-EOR as a climate solution.



=73%
of the total current capture capacity

Carbon Capture and Utilisation (CCU)

Carbon Capture and Storage (CCS): Carbon is captured from a stationary source, such as power generation plants, and is transported to sites and stored in saline aquifers or other underground deposits – and is not used for enhanced oil recovery (EOR).



=1%

of the total current capture capacity

Carbon Capture

- **Other carbon dioxide removal technologies (CDR)** includes Bioenergy with Carbon Capture and Storage (BECCS) and
- **Direct Air Carbon Capture and Storage (DACCS)** which are not well advanced technically and commercially.

Case Studies

13 flagship projects have captured more than two-thirds of the 300 million tonnes (MT) of anthropogenic CO_2 captured in history, and account for around 55% of the total current operational capacity worldwide.

Natural Gas Processing

- About 69% of total operational capacity worldwide.
- Involves separating CO_2 from extracted gas to produce natural gas (methane).

These projects account for about half of the active CCS projects in the natural gas processing sector, capturing an estimated two-thirds of the total CO_2 captured in the sector:

1. **Shute Creek, U.S.:** Lifetime under-performance of around 36%.
2. **Gorgon, Australia:** Under-performing capture targets by about 50%.
3. **Sleipner, Norway:** Performing close to the capture capacity.
4. **Snøhvit, Norway:** Performing close to the capture capacity.
5. **In Salah, Algeria: Failed, suspended 2011.**

1986
Shute Creek

Largest and one of the oldest carbon capture projects in the world

CO_2 Capture capacity: 7 million tonnes per annum

It is estimated that the lifetime under-performance of the project against its capturing capacity is approximately equivalent to the combined emissions from Sweden

↓

Lifetime under-performance of 36%

Enhanced oil recovery

1996
Sleipner

First commercial carbon capture project with a dedicated geological structure worldwide

CO_2 Capture capacity: 0.9 million tonnes per annum

It is among a few successful cases located in Norway. An exceptionally high carbon tax and stringent regulatory environment linked to the ETS are among the drivers. The gas project is in its tail of production lifetime.

↔

Performing close to the capture capacity

Dedicated geological structure

2004
In Salah

One of the largest operating CCS projects of our time

CO_2 Capture capacity: 1.1 million tonnes per annum

Started in 2004. Concerns about possible vertical leakage into the caprock led to investigations, and finally, the project was suspended in 2011.

⊘

Failed after seven years of operation

Dedicated geological structure

2007
Snøhvit

One of the two successful Norwegian carbon capture projects

CO_2 Capture capacity: 0.7 million tonnes per annum

It is one of the successful cases which is located in Norway. An exceptionally high carbon tax and stringent regulatory environment linked to the ETS are among the drivers

↔

Performing close to the capture capacity

Dedicated geological structure

2019
Gorgon

Largest and one of the more recent CCS projects in the world

CO_2 Capture capacity: 4 million tonnes per annum

Started after 3.5 years delay with a track record of technical failures. Compensating under-performance will cost up to US$184 million.

↓

Under-performing by ~50%

Dedicated geological structure

Industrial Sector

- About 25% of total operational capacity worldwide.
- Used in producing fertilisers, ethanol, iron and steel, hydrogen and other chemical productions that account for 65% of the total existing industrial carbon capture capacity.

These projects account for about 65% of the current capacity of CCS/CCUS projects in industrial applications:

1. **Abu Dhabi CCUS, United Arab Emirates:** CO2 is used to increase oil production - No outcome data has been published publicly.
2. **Quest, Canada:** Performing close to its designed capture capacity.
3. **Great Plains CCUS, U.S.:** Lifetime under-performance of 20% - 30%.
4. **Illinois Industrial CCS (IL-CCS), U.S.:** Under-performing by about 45% to 50%.
5. **Coffeyville, U.S.**: No public data found on lifetime performance. Some research shows over-performance in 2017-2019 by about 16%.

2000
Great Plains

The largest carbon capture project in all sectors other than natural gas processing

CO_2 Capture capacity: 3 million tonnes per annum

The project started capturing CO_2 16 years after the syngas plant was commissioned. In 2022, it has been planned to be redeveloped into a blue hydrogen project.

↓

Lifetime under-performance of 20–30%

Enhanced oil recovery

2013
Coffeyville

The largest project operating in the fertiliser production sub-sector

CO_2 Capture capacity: 0.9 million tonnes per annum

Only some research shows that the plant over-performed during 2017–2019 by about 16%. The CO_2 was vented until the year 2013, then some agreements with nearby oil companies were finalised to sell the CO_2

No public data was found on the lifetime performance.

Enhanced oil recovery

2017
Illinois Industrial Carbon Capture & Storage (IL-CCS)

The largest and the latest project commissioned in the ethanol production

CO_2 Capture capacity: 1 million tonnes per annum

Started in 2004. Concerns about possible vertical leakage into the caprock led to investigations, and finally, the project was suspended in 2011.

↓

Lifetime under-performance of 45–50%

Dedicated geological structure

2015
Quest

One of the operating projects in the hydrogen production sub-sector operating at its design capacity

CO_2 Capture capacity: 1.1 million tonnes per annum

The project got off the ground thanks to huge government funding estimated at C$95 per tonne of CO2 captured until the end of the project's lifetime. It captures 35% of the CO_2 emissions of the oil upgrader.

↔

Performing close to the capture capacity

Dedicated geological structure

2016
Al Reyadah

The first and only CCS plant in the steel sub-sector

CO_2 Capture capacity: 0.8 million tonnes per annum

The project is 100% government owned.

No public data was found on the lifetime performance.

Enhanced oil recovery

Power Sector

- Less than 3% of total operational capacity worldwide following Petra Nova closure.
- Involves retrofitting existing fossil-fuelled power plants with carbon capture facilities (post-combustion carbon capture) aiming to capture CO_2 after burning the fuel.
- Not commercially advanced and has not met performance targets.
- Close to 90% of proposed CCS capacity in the power sector has failed at the implementation
- stage or was suspended early.
- Not generally seen as cost competitive with renewables plus storage as a climate change mitigation option.

1. **Boundary Dam, Canada:** Under-performing by about 50%.
2. **Petra Nova, U.S.:** Failed, mothballed in 2020.
3. **Kemper Coal Gasification, U.S.:** Failed, closed in 2017.

2014
Kemper

(without Carbon Capture)
It was planned to be a first-of-a-kind plant

CO_2 Capture capacity:
3 million tonnes per annum

Technical problems led to a 250% increase in the previously estimated cost of the project from U$3b to US$7.5 billion.
The carbon capture idea was cancelled in 2017. It was the most expensive power plant ever built.

⊘
Failed to be started

Enhanced oil recovery

2013
Boundary Dam

The only project operating in the power sector worldwide

CO_2 Capture capacity:
1 million tonnes per annum

Started after 3.5 years delay with a track record of technical failures. Compensating under-performance will cost up to US$184 million.

↓
Lifetime under-performance by ~50%

Enhanced oil recovery

2017
Petra Nova

The only project in the power sector in the U.S.

CO_2 Capture capacity:
1.4 million tonnes per annum

in four years of its operation and then shut down.
↓
Lifetime under-performance of ~17%

Enhanced oil recovery

Conclusion

- Failed/ underperforming projects considerably outnumbered successful experiences.
- Successful CCUS exceptions mainly existed in the natural gas processing sector.

  The majority of CO_2 stored is used for enhanced oil recovery, leading to more emissions
- The elephant in the room – Scope 3 emissions.
- CCS/CCUS is an energy intensive process.
- Some applications of CCS in industries where emissions are hard to abate

  (eg cement production) CCS could be an interim solution.

Thank you

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