The Economic Impact of Cutting GHGs Using *Carbon Capture and Storage (CCS)*

By Esha, Jacki, Jacob, & Katie

32,000,000

Tonnes of CO_2 from industrial processes ***is*** removed globally using CCS technology each year

Source: BCG

44,000,000,000

Tonnes of CO_2 emissions per year ***needs*** to be removed globally using CCS technology by 2040 in order to meet Paris Agreement goals

Source: BCG

$90 Billion

Is the global CCS industry’s projected worth in the next decade

Source: BCG

CCS technology *could* play a critical role in the energy transition, **reducing CO2 emissions** from existing fossil fuel infrastructure while maintaining the **competitiveness of the US petrochemical and heavy industrial sectors** as the country continues to gain prominence as an independent oil producer.

Table of Contents

What is Carbon Capture & Storage?

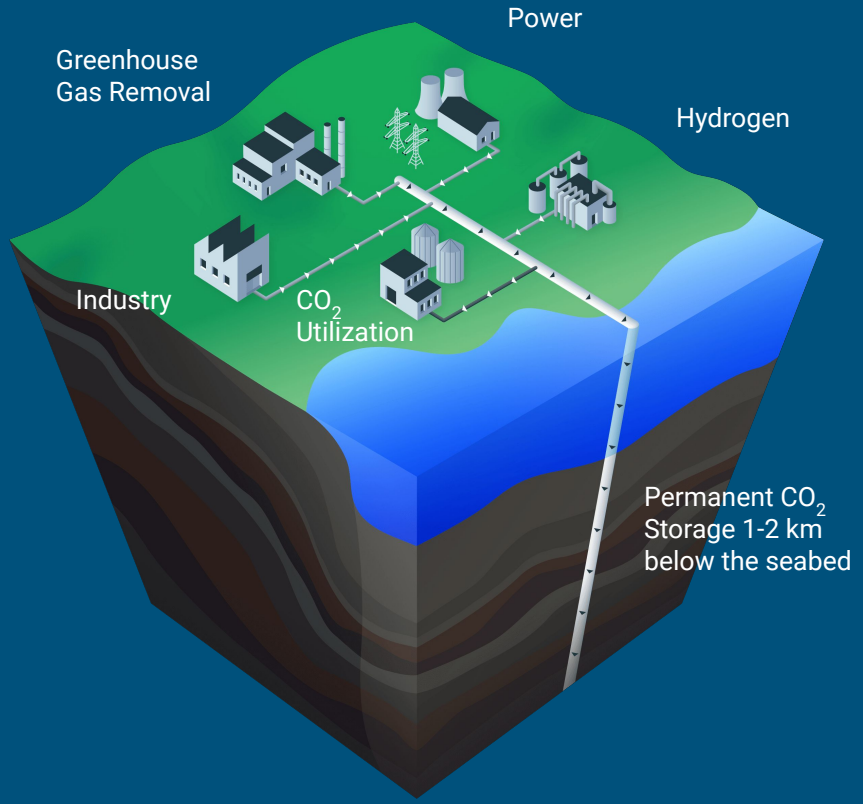
Carbon Capture & Storage (CCS) Explained

CCS is a technology used to prevent atmospheric CO_2 emissions from hydrocarbon-based processes. Also capable of removing existing CO_2 from the atmosphere.

Three Steps:

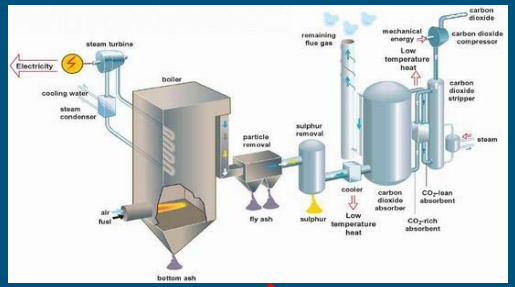
Capturing the CO2 → Transporting CO2 → Storing the CO2

Commercially viable since 1976, however still not widely used



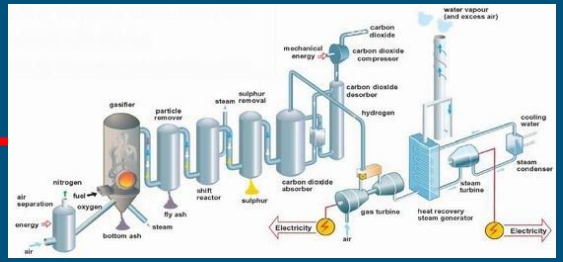
Source: http://www.ccsassociation.org/what-is-ccs/capture/

Carbon Capture Process



Pre-combustion

involves converting solid, liquid or gaseous fuel into a mixture of hydrogen and CO2 using ‘gasification’ or ‘reforming’

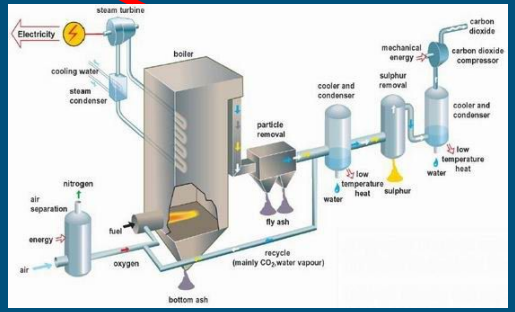


Post-combustion

CO2 can be captured from exhaust of combustion process by absorbing it in a suitable solvent

Oxy-fuel Combustion

oxygen is separated from air prior to combustion and the fuel is combusted in oxygen diluted with recycled flue-gas rather than by air

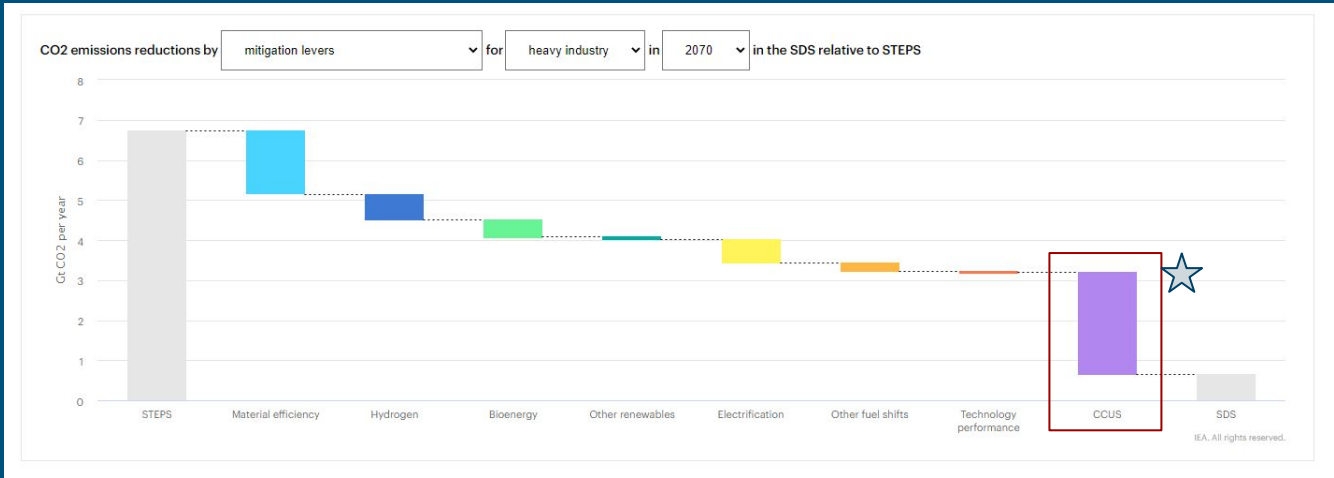


**Technological growth is most prominent within the carbon capture process*

Source: http://www.ccsassociation.org/what-is-ccs/capture/

2070 Projections: CO_2 Emission Reductions

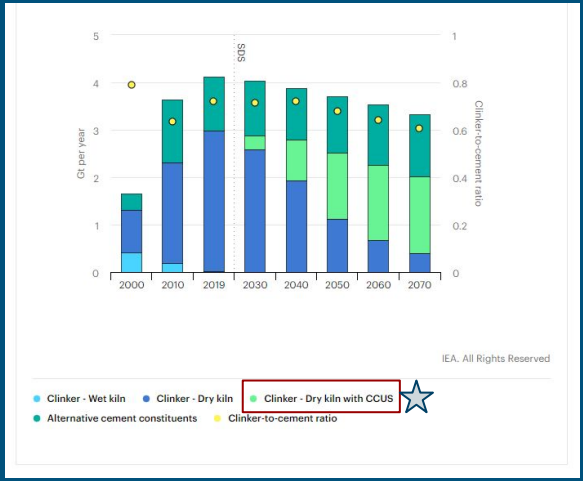
CCS effectiveness is most prevalent in heavy industry where it is difficult to reach zero emissions through alternative technologies.[1]



Source: [1]iea.org

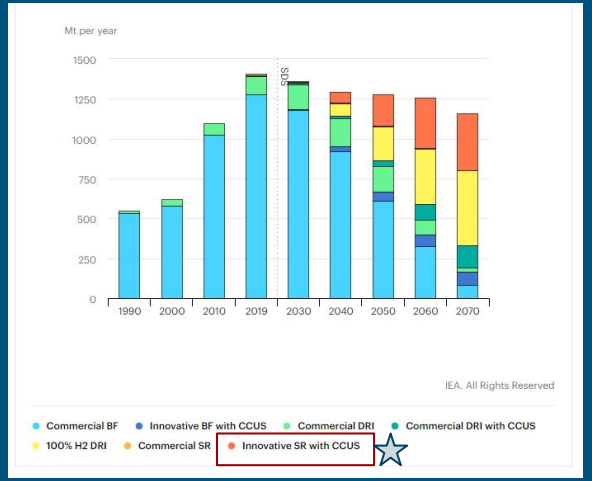
2070 Projections: Sustainable Cement/Iron Production

Global Cement Production by Technology in the SDS 2000-2070



"Despite these extensive changes, the impact on end-use consumers is expected to be small – the cost increase for steel would raise the price of a car by only about 0.2% and that for cement would raise the price of a house by only about 0.6%."[1]

Global Iron Production by Technology in the SDS 1990-2070



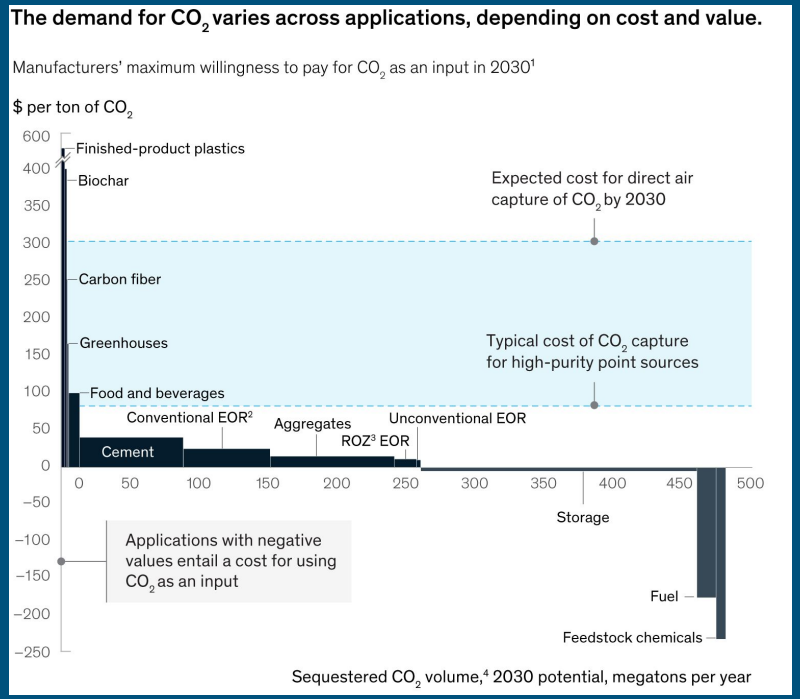
Source: [1]iea.org

CCS is a Key Player in the Energy Transition

Transitioning with Existing Infrastructure

- Decarbonization of existing infrastructure, targeting heavy industrial processes that are tough to decarbonize
- Paired with biomass, can create negative CO_2 emissions (also known as BECCS)
- Since 2017, more than 30 new integrated CCS facilities have been announced

- CO_2 is *in demand* across various industries as an input to produce goods, thus there is a market for its consumption
  - Enables use of carbon as a feed source, making carbon-intensive fuels less carbon-heavy

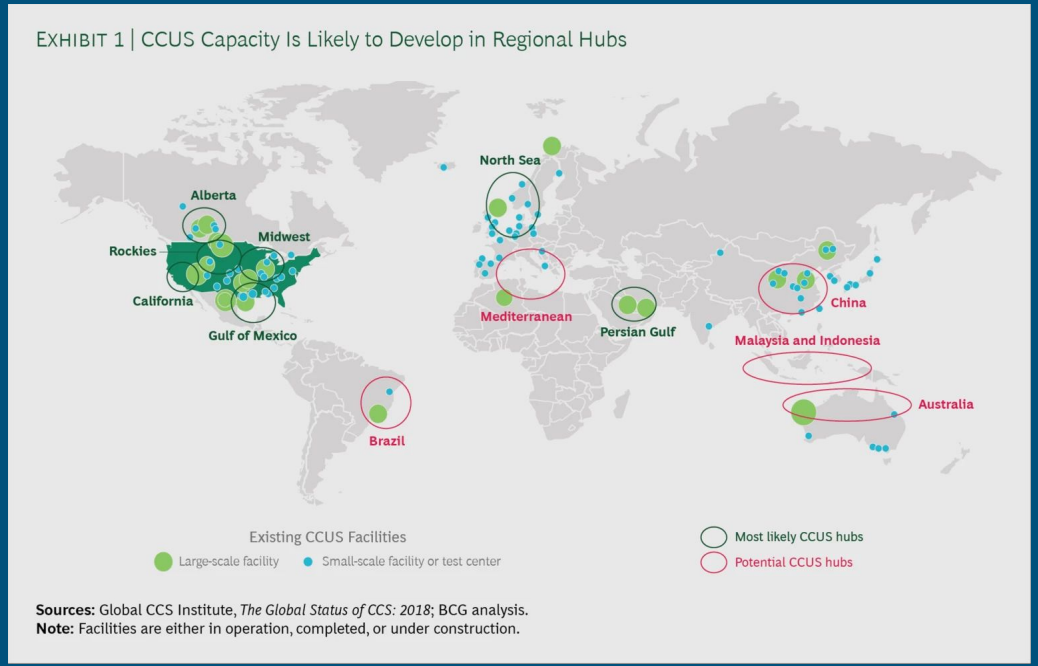


Source: Wood Mackenzie

Where is CCS Employed?

21 operational CCS projects **globally**

Only **two** of these are operating power plants with CCS:
Petra Nova in TX and Boundary Dam in Saskatchewan



Source: BCG

What are the US economics of CCS?

Is CCS Economically Viable?

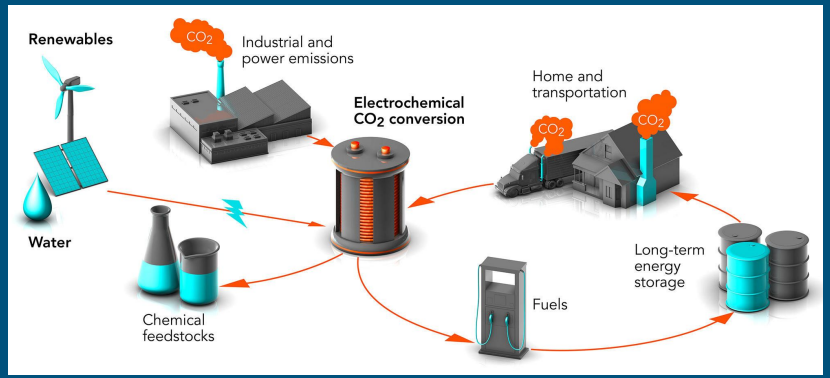
Limitations

- X High capture costs, tech limitations in developing CO_2 as a feedstock, and a lack of global regulatory incentives (tax credits, etc.)
- X Storing CO_2 has no return on investment; it's a pure cost
- X Tricky legal issues surrounding storage underground

Potential

- ✓ Could reduce >90% of carbon emissions from industrial processes
- ✓ Could expand from 50 Mtpa to 500 Mtpa, reducing 1% of today's annual emissions with supportive regulatory framework in place

CO_2 can be captured and sold rather than buried underground



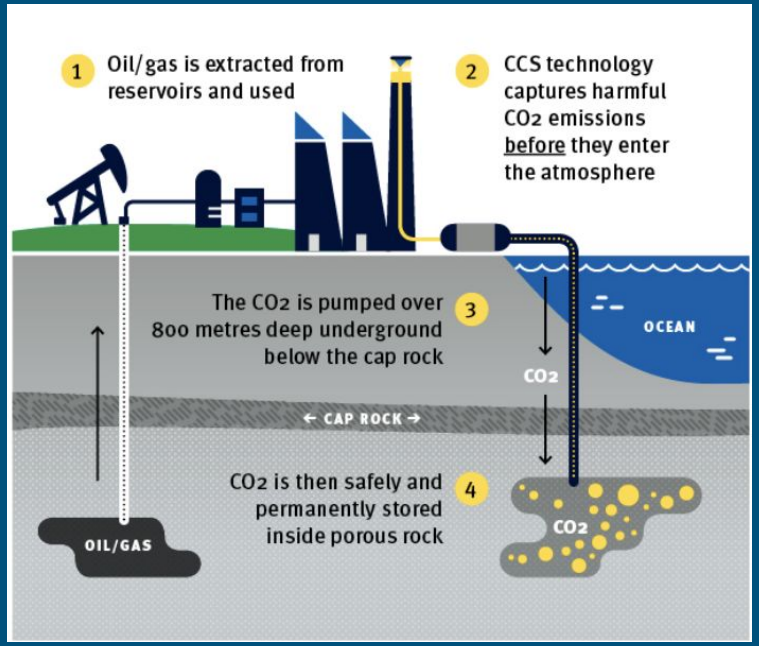
Source: Stanford Earth, McKinsey

Corporate Investments in CCS

Oil & Gas Spending on CCS and EOR

Enhanced Oil Recovery

- Oil producers have an economic purpose for CO_2
- Pressurized CO_2 enhances hydrocarbon extraction
- Recovered oil is used by power plants and refineries, becoming more economically attractive
- EOR accounts for >80 Mtpa of CO_2 emission reduction across conventional reservoirs, residual oil zones, and unconventional oil fields



Source: Imperial College London Sustainable Gas Institute (2016), iea.org, McKinsey

Carbon Capture isn't Cheap.

Standalone Costs for CCS:

- X With current technology implemented at scale, it costs $80-$160 a metric ton to capture and store CO_2 produced by natural gas power plants
- X $125-$449 a metric ton to take the gas out of the ambient air

Cost Benefits with Combined Technology:

- ✓ Using a combination of EOR and CO_2 storage can reduce CCS cost by 0.01-0.02 US$/kWh
- ✓ Biomass co-firing could reduce 110 US$/t$CO_2$ avoided

Since 2000, US taxpayers have invested almost $4 billion in CCS

Source: Energy Post

“**Virtually every fossil fuel company** in the world right now is leaning into **largely unproven, prohibitively expensive new technologies** so as to extend the life of its **core business model** indefinitely.”

Source: New Republic

Creating Value in CCS Projects

Three Markets for CCS Deployment

Clumping CCS technology users that have existing pipeline infrastructure reduces the cost of transporting CO_2

Industrial processes with highly concentrated CO_2 streams

$30-$50

Per metric ton of CO_2

Petroleum refiners and manufacturers of cement, lime, aluminum, iron, and steel

<$50->$200

Per metric ton of CO_2

Power generation (highest-cost sector due to expensive retrofitting of plants)

$40-$170

Per metric ton of CO_2

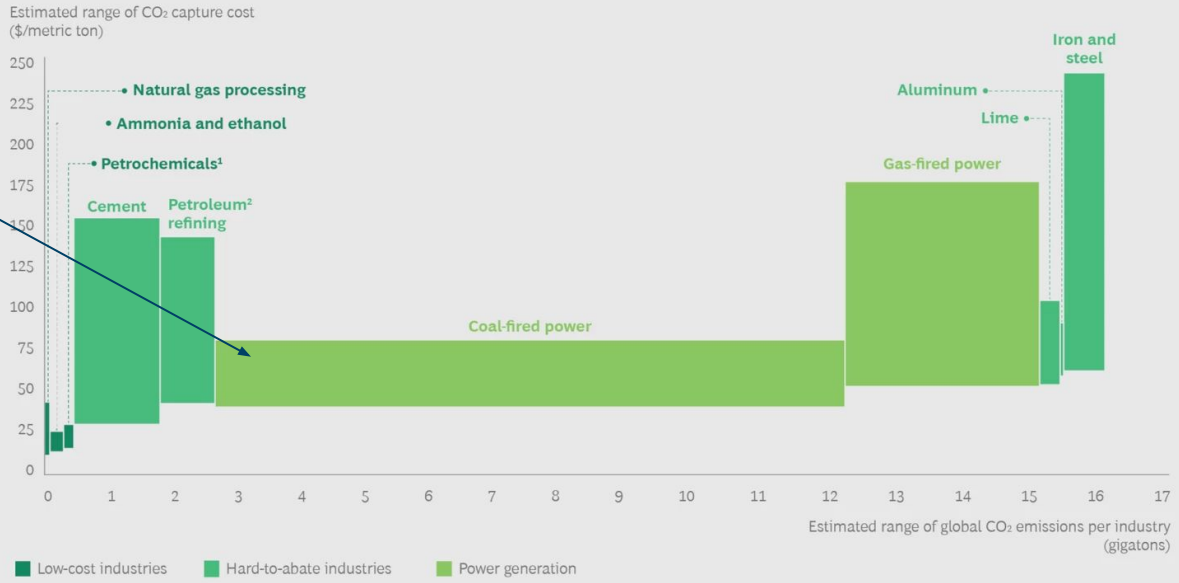
Source: [1]BCG

Target Market:
Coal-Fired Power Plants

Coal-fired power plants emit the **most** carbon out of the three industries yet have the **least** expensive capture costs

Coal accounted for 23.4% of US electricity production in 2019[1]

EXHIBIT 2 | Three Market Segments for Carbon Capture



Sources: BCG proprietary carbon capture model–estimated cost ranges are based on published literature and public statements; sector-specific emissions data is based on International Energy Agency estimates.
Note: Exploration and production (E&P) is excluded from curve owing to lack of cost estimates. Cost curve reflects range of estimates and excludes some outliers, so it should be considered illustrative.
[1]Only includes high-concentration CO_2 streams.
[2]Includes emissions from fossil-based hydrogen production (i.e., from steam methane reforming).

Source: BCG, [1]eia.gov

CCS is a Fledgling Industry

Improving Technology & Increasing CO_2 Demand

- Developments lowering the cost of capturing carbon and increasing the value of captured CO_2 could give rise to a market for carbon

- Solvent-based technological improvements in pre-/post-combustion processes could reduce costs where CO_2 concentration is low

- Possible that CO_2 used as an industrial feedstock could use more than 1 gigaton of CO_2 a year

Creating Value in Four Ways

1. Low-cost standalone CCS applications are becoming more profitable with processes that produce concentrated CO_2 streams
2. Pilot Projects funded by the government could develop CCS markets so that they are more lucrative in the future
3. "Green" cement and mineralization could become commercially viable
4. Long-term strategy is to invest in CO_2 capture technology that needs significant R&D but would greatly improve the CCS process

Sources: BCG, McKinsey & Co.

Government Incentives for CCS in the US

Section 45Q Tax Credits

Section 45Q of the Internal Revenue Code provides a per-ton tax credit for carbon sequestration in the U.S.[1]

Updated with the Bipartisan Budget Act of 2018, 45Q grants a $50 tax credit per ton of CO_2 permanently sequestered or a $35 tax credit per ton of CO_2 sequestered for enhanced oil recovery.[2]

Source: [1]Internal Revenue Code, [2]Bipartisan Budget Act

Section 45Q Tax Credit Impact

2008

Since it was passed in 2008, 20+ major CCS projects have been publicly announced in the U.S.[1]

2024

Currently, 45Q has a construction deadline of January 1, 2024

Many of these projects will struggle to make this deadline due to the difficulty of financing projects. Investors largely value a direct pay incentive over the tax credits.

Source: [1]Clean Air Task Force

45Q is Making Carbon Capture Economical

The IRS recently released guidance to aid parties in developing CCS projects and taking advantage of tax credits.[1]

Developers are using this guidance to help create more jobs in a time when COVID-19 has driven up unemployment in the U.S.

Case Study: ***Enchant Energy Corp.***[2]

- Enchant Energy Corp. is planning to implement a CCS system at a coal-fired power plant in New Mexico.
- The plant was slated to close in 2022, and Enchant Energy will save ~450 jobs by repurposing the plant for carbon capture.
- Because of 45Q tax credits, Enchant Energy can keep the plant in operation once they install a $1.3 billion CCS system.
- Construction will begin in 2021.

ENCHANT ENERGY CORPORATION

Source: [1]IRS, [2]Enchant Energy

45Q and Enhanced Oil Recovery

The main economic incentive for CCS is Enhanced Oil Recovery (EOR).

- EOR **increases oil recovery** by up to 15% with a **net CO_2 reduction**.[1]
- 45Q grants tax credits to carbon sequestered for EOR purposes.
- This results in an **increase in domestic oil**, thereby **reducing imported oil**.[2]
- EOR is the only **large-scale, permanent** application of CCS that produces a **profit**.
- EOR can help **increase the scale** of CCS projects while **driving down costs**.

Source: [1]National Energy Technology Lab, [2]Columbia Energy Policy

Jacob Eskeland

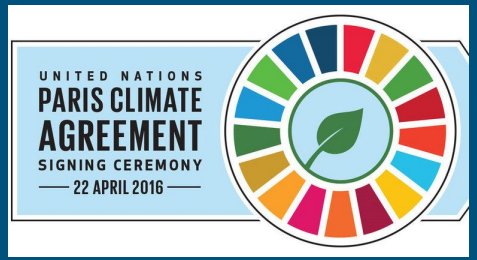
Guest Speaker

CCS in Norway

CCS to Reduce Greenhouse Gases in Norway

The Paris Agreement

- Through the Paris agreement, Norway has committed to reduce emissions with at least 50%, and towards 55% by 2030



Current Emission Situation

- Petroleum activity and industry are the main culprits of emissions
- More than 20 years of experience with CO_2 management on an industrial scale

The Sleipner natural gas platform with a CO_2 separation unit in the center

Source: [1]Equinor ASA

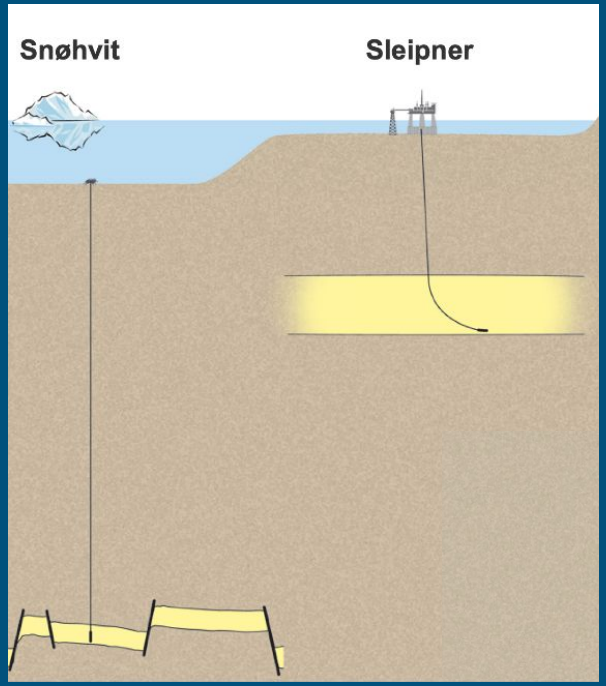
Sleipner and Snøhvit

Sleipner

- 1996 – present
- The world's first offshore CCS facility
- Due to the high carbon tax it was profitable
- Without CO_2 storage, the cost of taxes would be more than $50m annually
- Annual storage of 1 million tons CO_2, no evidence of leakage

Snøhvit ("Snow White")

- 2008 – present
- LNG project in the Barents Sea, offshore
- CO2 is captured and separated from natural gas onshore and then transported in a 153 km subsea pipeline
- Annual storage of 0.7 million tons CO_2

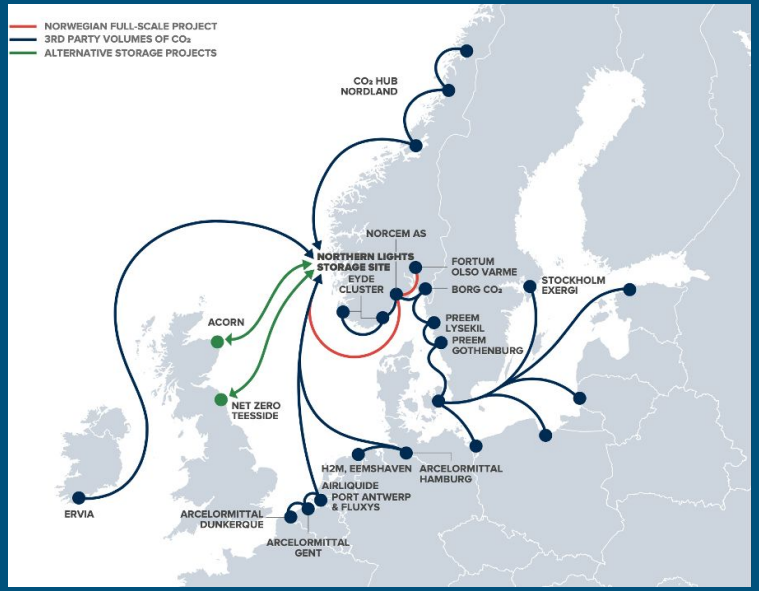


Source: https://www.clsforum.org/, https://lovdata.no/dokument/STV/forskrift/2017-12-12-2187

The North Sea as a Centralized Storage Facility for European CO_2?

Hubs & Clusters Strategy

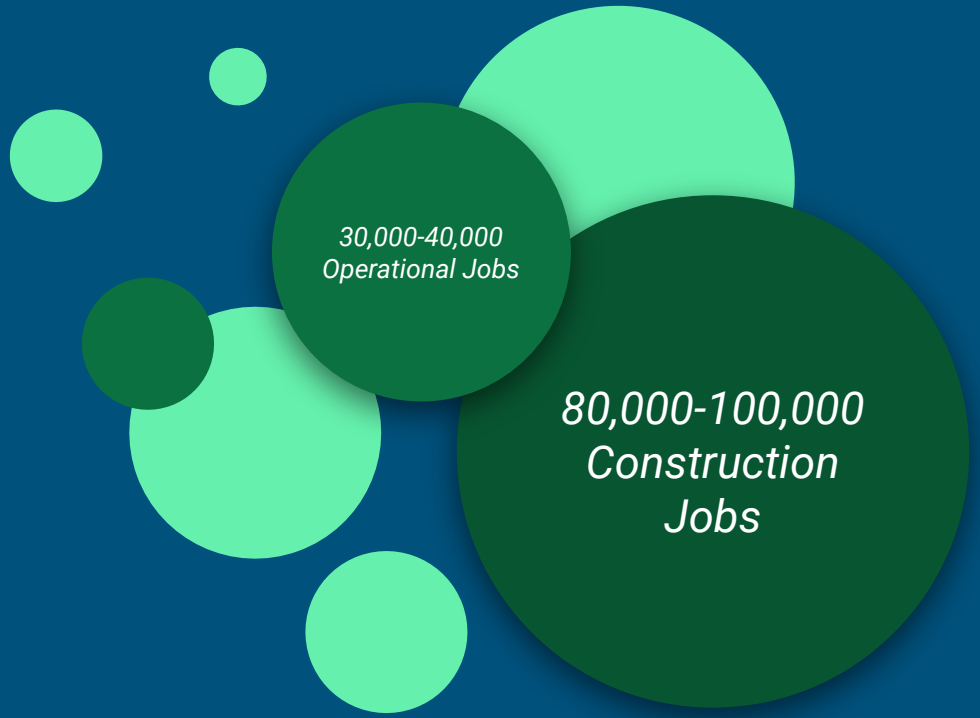
- A hubs and clusters strategy will allow for shared infrastructure and decreased unit costs across the CCS value chain
- European public opposition to onshore storage
- “Northern Lights” – a full scale CCS project scheduled to operate from 2024
- Collaboration between Equinor, Shell and Total



Hypothetical sources of carbon for “Northern Lights”

Source: [1] GCC Report: Global Status of CCS 2019

Job Creation



By 2050, CCS construction could employ 80,000-100,000 people globally along with 30,000-40,000 people needed for operation of CCS facilities

Source: https://www.globalccsinstitute.com/wp-content/uploads/2020/04/Value-of-Carbon-Capture-and-Storage-V4-1.pdf

CCS *could* be a key component in the world's development towards carbon neutrality as we balance economic growth and reducing emissions.

Energy illustrated

CCUS

WHAT IS CCUS?

DECARBONISE INDUSTRIAL PROCESSES BY PREVENTING EXHAUST CO_2 FROM ENTERING THE ATMOSPHERE

CARBON CAPTURE UTILISATION AND STORAGE

NEAR-ZERO CARBON ENERGY WHEN NATURAL GAS IS USED WITH CCUS

HOW DOES IT WORK?

1. CO_2 IS SEPARATED FROM THE EXHAUST GASES FROM
   - INDUSTRIAL PROCESSES
   - POWER GENERATION
   - BLUE HYDROGEN MANUFACTURE

EXHAUST GASES

WHEN NATURAL GAS IS REFORMED WITH STEAM AND THE CO_2 IS CAPTURED, THIS PRODUCES BLUE HYDROGEN

CLEAN ENERGY CAN BE USED FOR
- POWER
- INDUSTRY
- TRANSPORT

2. TRANSPORTED FROM SOURCE

3. STORED SECURELY INTO A GEOLOGICAL FORMATION DEEP UNDERGROUND

4. CO_2 MAY BE UTILISED TO GENERATE USEFUL PRODUCTS WHERE THE CARBON IS LOCKED UP

BECCS

BIOENERGY WITH CARBON CAPTURE AND STORAGE

BIOMASS CAPTURING AND STORING CO_2 TO GENERATE ELECTRICITY

CAN BE USED TO CREATE A NEGATIVE EMISSIONS ENERGY SOURCE

WHICH CAN OFFSET EMISSIONS FROM HARD TO ABATE SECTORS SUCH AS AVIATION

1.5 BILLION TONNES OF NEGATIVE EMISSIONS IS FORECAST TO BE NEEDED BY 2050 IN A NET ZERO WORLD

KEY PART OF THE UK STRATEGY TO GET TO NET ZERO BY 2050

NET ZERO TEESSIDE OPENING 2026

CAPTURE UP TO 10M TONNES OF CO_2

EQUIVALENT TO THE EMISSIONS OF AROUND 3 MILLION UK HOMES

NORTH SEA

POTENTIAL TO STORE 1 BILLION TONNES

CCUS IN A NET ZERO WORLD

ANNUAL INVESTMENT OF $150bn REQUIRED

5 BILLION TONNES OF GLOBAL EMMISSIONS FROM ENERGY CAPTURED AND STORED

3/4 OF NATURAL GAS IS USED WITH CCUS

2050

CCUS KEY LEVER TO REACH NET ZERO EMISSIONS


Q&A

Appendix

Case Study: CCS in Power Plants

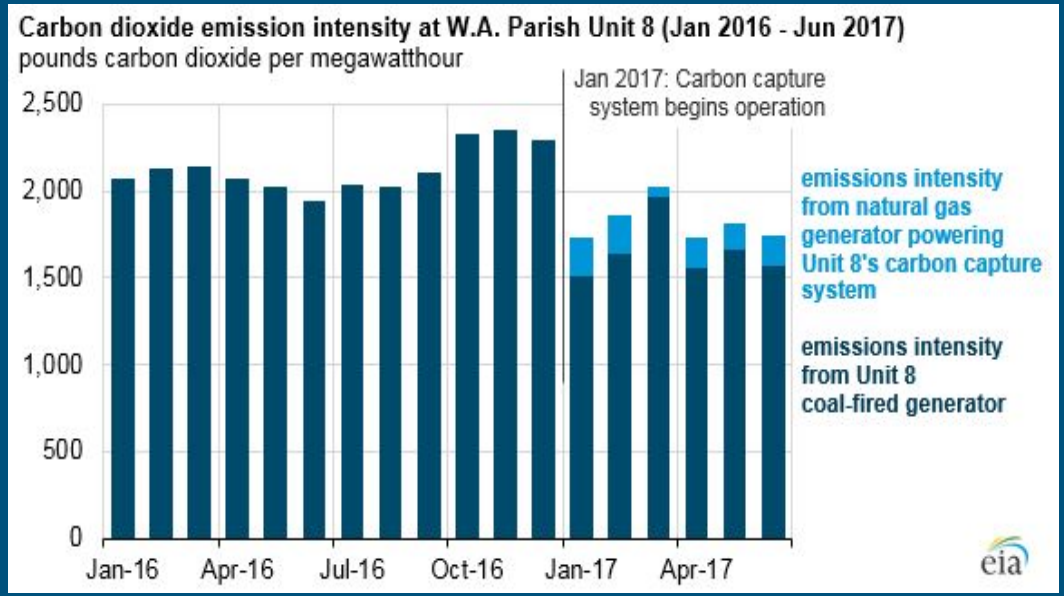
Petra Nova Power Plant

Located at Unit 8 of the W.A. Parish plant outside of Houston, Texas

Closed in 9/20!

Efficacy & Cost

- ✓ Captures approximately 90% of the CO2 from flue gas stream
- ✓ Estimated to have cost more than $1 billion (equates to $4,000/kW)



Source: U.S. Energy Information Administration, based on U.S. Environmental Protection Agency Air Markets Program Data

CCS Economics Compared to Renewables

CCS Compared to Renewables

Energy Return on Energy Invested (EROEI)

Ratio of usable energy to the energy invested in the construction, operation, and fuel procurement for power plants

~

Fossil-fuel-based power plants w/ CCS (assuming 90% of CO2 is captured) is much less favorable compared to the current EROEI of scalable renewable energy resources without storage (mainly due to loss of energy associated with building and operating CCS processes resulting in lower net energy output from coal and gas power stations with CCS)[2]

"Critics also say it is a Band-Aid solution and the long-term consequences of storing carbon dioxide underground are uncertain."[1]

"Media stories about the promise of carbon capture will continue to appear — [...] — and the oil industry will continue to promote the idea that carbon capture will allow for continued burning of fossil fuels without harming the climate or environment, which is technically impossible."[3]

Source: [1]anthropocenemagazine.org, [2]europeanscientist.com, [3]resilience.org

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