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Federal Section 45Q Carbon Capture Credits Explained
Accelerating Net-Zero with CCUS

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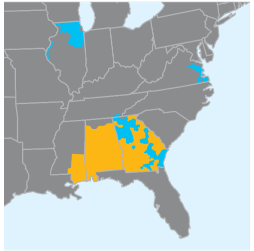
NATIONAL CARBON CAPTURE CENTER

Providing Clean, Safe, Reliable & Affordable Energy

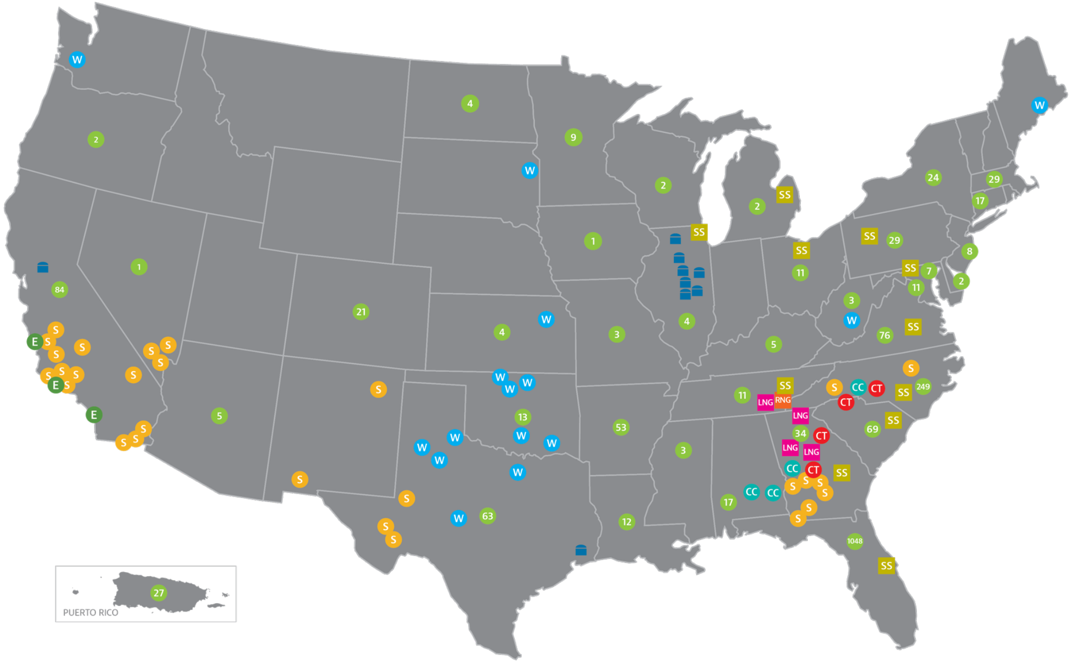


Service territories

- Electric
- Gas

Gas pipelines

- Southern Natural Gas
- Southern Company Gas



Southern Power

- Combined-cycle facility
- Peaking facility
- Solar facility
- Wind facility
- Energy storage

Southern Company Gas

- LNG facilities
- SouthStar
- Natural gas storage
- Renewable natural gas

PowerSecure

- Owned and/or managed sites per state

Capabilities in **50 States**

7 Electric & Natural Gas Utilities

9 Million Customers

Approximately **28,000** Employees

Approximately **42,000 MW** of Generating Capacity

Southern Company

February 2022

Southern Company's Commitment to Net Zero

Our energy strategy includes the continued development of a diverse portfolio of resources, driven by RD&D, to serve customers and communities with a focus on reducing greenhouse gas emissions

2007

Baseline

2020

Reduced[1] 52%

2030

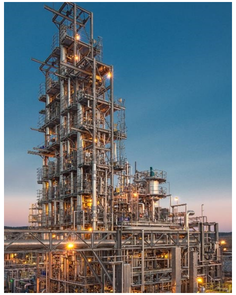
50% Reduction Goal

2050

Net Zero Goal

[1] The reduction in GHG emissions from 2019 to 2020 was primarily driven by milder weather, decreased customer energy usage resulting from the COVID-19 pandemic, and the continued transition to lower- and non-emitting resources. Expect to achieve sustainable reduction of at least 50% in 2025, if not earlier.

Southern Company Strategic CCUS Activities



- **National Carbon Capture Center**

  Reduce capture costs / advance technologies

  – 134,000+ test hours / 70 technologies / +40% cost reduction

  – Expanded to natural gas combined-cycle (NGCC) power, CO_2 utilization, direct air capture (DAC)

- **FEED Studies**

  Critical to establishing capital costs for capture

  – **CO_2 Capture on Natural Gas:** Linde-BASF system at Mississippi Power's Plant Daniel NGCC Plant

  – **Black & Veatch DAC:** Scale-up of Global Thermostat's DAC system coupled with combined heat & power turbine

  – **GE's Retrofittable Advanced CC Integration for Flexible Decarbonized Generation**: 95% carbon capture at Alabama Power's Plant Barry NGCC with Exhaust Gas Recycle

  – **Battelle NuDACCS**: advanced DAC system capitalizing on rejected heat from existing nuclear plant (Alabama Power's Plant Farley)

- **Storage Resource Assessments**

  Ready-to-go storage sites

  – **DOE/NETL CarbonSAFE:** Development of a strategic, high-storage-capacity regional storage hub in Kemper County, MS

  – **Extensive CO_2 Source-Sink Site Characterizations Projects**

    ✓ Demonstration and pilot integration injections studies for storage capacity

    ✓ New resource assessment wells being drilled each year to fill in gaps

    ✓ Source-sink infrastructure modeling for cost basis

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U.S. DEPARTMENT OF ENERGY

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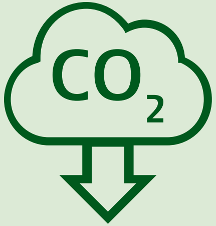
Positive developments with CCUS



RD&D continues to drive down cost of capture technologies

- ✓ Second-generation is readying for deployment; transformational is in development (scale-up required)
- ✓ FOAK to NOAK commercial demonstration with established technologies significantly reduces costs

Policy incentives such as the Section 45Q tax credit and Bipartisan Infrastructure Law (BIF) are driving investment

Regulatory and legal project risk is being reduced

U.S. DEPARTMENT OF ENERGY

DOE Fossil Energy and Carbon Management's focus on CCUS

Federal agencies and state governments are now directly supporting CCUS deployment (EPA, BOEM/BSSE, DOI, etc.)

Workforce development and supply chain is developing

Inflation Reduction Act (2022)

Source of Carbon Dioxide	Storage Method	EIEA 45Q Value (per metric ton)	BBA 45Q Value (per metric ton)	IRA 45Q Value (per metric ton)
Industrial Facility (including electric generating units)	Enhanced Oil Recovery (EOR) with Geologic Storage or Utilization	**$10/ton**	**$35/ton**	**$60/ton**
Industrial Facility (including electric generating units)	Geologic Storage without EOR	**$20/ton**	**$50/ton**	**$85/ton**
Direct Air Capture Facility	EOR with Geologic Storage or Utilization	N/A	$35/ton	$130/ton
Direct Air Capture Facility	Geologic Storage without EOR	**N/A**	**$50/ton**	**$180/ton**

IRA Key Points

Effective date: Pushes out commence construction from Jan. 1, 2026, to Jan. 1, 2033.

Qualified facility: Language lowered qualified facility volume definition. An electric generating facility must capture at least 18,500 tons per year.

Direct pay: Provides **direct pay for private entities for 5 years**. Those entities are then eligible to use transferability. Public entities can elect to receive direct pay for the life of the credit (12 years).

1 million metric tons (MMt)/year x $85/tonne x 12 years = >$1B

Project partnerships between emitters, operators & landowners

- **HOUSTON**, March 28, 2022 – **Occidental's Oxy Low Carbon Ventures** (OLCV) and **Weyerhaeuser Company** today announced an agreement for the evaluation and potential development of a CCS project in **Livingston Parish, Louisiana**. The lease agreement provides OLCV with exclusive rights to operate a carbon sequestration hub on more than **30,000 acres of subsurface pore space** controlled by Weyerhaeuser. OLCV will use the land to permanently sequester industrial CO_2 in underground geologic formations not associated with oil and gas production, while Weyerhaeuser continues to manage the aboveground acreage as a working forest.

- **PLANO, Texas**, Feb. 7, 2022 – **Denbury Carbon Solutions LLC** and a subsidiary of **Natural Resource Partners L.P.** have executed a CO_2 sequestration agreement for the evaluation and potential development of a permanent CO_2 sequestration site on **Alabama's Gulf Coast**. The agreement provides Denbury with exclusive rights to develop a CO_2 sequestration site on approximately **75,000 acres** of pore space controlled by NRP in Baldwin County, near Mobile. Denbury estimates the total CO_2 storage potential to be **over 300 million metric tons**.

- **AMES, Iowa**, Feb. 1, 2022 – **Summit Carbon Solutions** announced further progress on its CCS project with the filing of its pipeline permit application in the state of Iowa. Summit's project will connect ethanol biorefineries across five states in the **upper Midwest – Iowa, Minnesota, Nebraska, North Dakota and South Dakota** – with the largest portion of the project, consisting of **12 ethanol biorefineries and over 680 miles of CO_2 pipeline**, in Iowa. By capturing and permanently storing CO_2 emissions from partner ethanol biorefineries, Summit will cut the carbon footprint of their ethanol in half, ensuring the environmental and economic sustainability of these facilities.

- **DALLAS,** Dec. 22, 2022 – A **Texas offshore oil and gas operator** is partnering with a Louisiana pipeline company and a **Spanish energy firm** to develop a **Gulf of Mexico** carbon capture hub. **Carbon-Zero US LLC** of Dallas has applied for DOE funds to develop a pilot sequestration hub in offshore storage fields about 20 miles from **Grand Isle**, according to **Cox Operating LLC**, the Dallas operator that owns some of the storage fields. The other storage fields are owned by **Crescent Midstream**, a pipeline distribution group that will help transport CO_2 to the Grand Isle hub. In addition, Crescent Midstream has completed an initial study for a new 110-mile CO_2 pipeline from Geismar to Grand Isle.

Project partnerships between emitters, operators & landowners

- **BATON ROUGE, La.**, Oct. 12, 2022 – Gov. John Bel Edwards and global energy corporations **CF Industries**, **ExxonMobil** and **EnLink Midstream** announced a collaboration aimed at dramatically reducing industrial CO_2 emissions in Louisiana. The companies have entered into the largest-of-its-kind commercial agreement to capture emissions from **CF Industries' Ascension Parish manufacturing complex**, transport the CO_2 through EnLink's transportation network and permanently store it underground on property owned by ExxonMobil in **Vermilion Parish**.

- **ARVADA, Colo. & BRIDGEPORT, Neb.**, Oct. 4, 2022 – **Carbon America** announced today an agreement with **Bridgeport Ethanol, LLC** to develop a CCS project in **Nebraska**. The project will capture and store approximately 175,000 tons of CO_2 per year, equivalent to 95% of total emissions from the ethanol facility's fermentation process. This is Carbon America's third agreement this year to finance, build, own and operate CCS systems at ethanol facilities. In May, the company announced agreements with Sterling Ethanol LLC and Yuma Ethanol LLC to develop CCS projects at their respective Colorado-based biorefineries, expected to be operational in 2024.

- **HOUSTON**, May 3, 2022 – **Chevron USA**, **Talos Energy** and **Carbonvert** announced today a memorandum of understanding for an expanded joint venture to develop the **Bayou Bend CCS offshore CCS hub** currently held by Talos and Carbonvert. The Bayou Bend CCS site encompasses over 40,000 gross acres and could potentially **sequester 225 to 275 million metric tons** of CO_2 from industrial sources in the area. The Bayou Bend CCS lease is the **first and only offshore lease in the U.S. dedicated to CO_2 sequestration**.

- **PLANO, Texas & SEATTLE, Wash.**, Dec. 12, 2022 – **Denbury** and **Weyerhaeuser Company** today announced an agreement for the potential development of a CO_2 sequestration site in **Mississippi**. The lease agreement provides Denbury exclusive right to develop and operate approximately 16,000 acres of subsurface pore space owned by Weyerhaeuser in Simpson and Copiah Counties. Denbury plans to use the site to permanently sequester industrial CO_2 in secure underground geologic formations. Weyerhaeuser will manage the timberland acreage as a sustainable working forest. Denbury estimates the site will have total storage capacity of approximately **275 million metric tons of CO_2**

Infrastructure Investment and Jobs Act (2021)

Signed into law on Nov. 15, 2021, the **Infrastructure Investment and Jobs Act** totals **$1.2 trillion** in funding over the next 5 years for infrastructure. Funding aligns with climate goals that include net-zero economy emissions by 2050 and 100% carbon-free electricity by 2035.

The INFRASTRUCTURE INVESTMENT and JOBS ACT

- ***Appropriations for CCUS Programs – Total $12.1 billion***
  - CCUS Demonstration Projects - $2.5 billion
  - CCUS Pilot Projects - $937 million
  - CO_2 Storage Validation and Testing - $2.5 billion
  - CO_2 Infrastructure Finance and Innovation - $2.1 billion
  - Class VI Well Permitting - $75 million
  - Front-End Engineering and Design Studies for CO_2 Transport Infrastructure - $100 million
  - CO_2 Utilization - $310.14 million
  - Regional Direct Air Capture (DAC) Hubs - $3.5 billion
  - Commercial DAC Technology Prize - $100 million
  - Precommercial DAC Prize - $15 million

Related legislation

- Section 40314 – Proposed $8 billion for clean hydrogen hubs and project financing including fossil fuels with carbon management

Department of Interior

- Section 40307 – Congressional language on geologic carbon sequestration providing DOI jurisdiction for the outer continental shelf
- Section 40601 – Orphan well site plugging, remediation and restoration: $4.7 billion

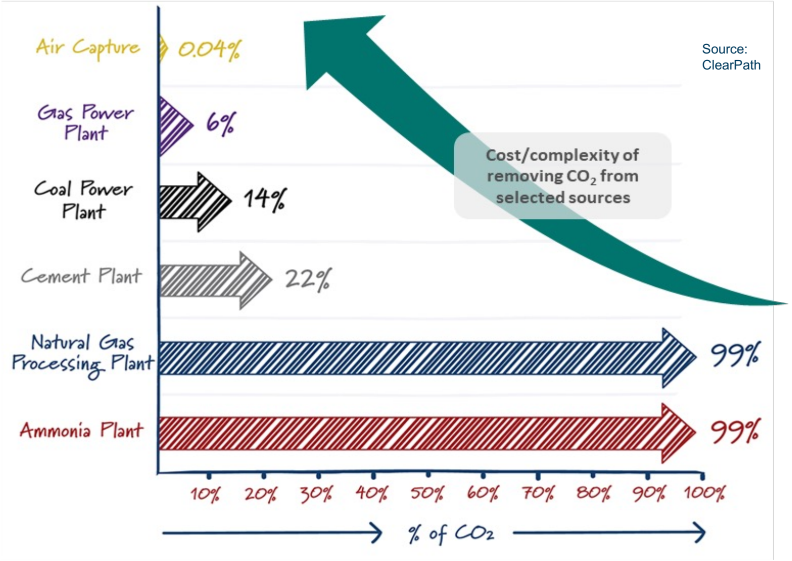
Environmental Protection Agency

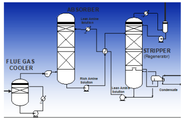
- Section 40306 – Support for Class VI UIC permitting and state primacy efforts: $75 million

Challenges to Widespread Utility CCUS

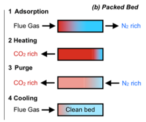
- Overall challenges – capital cost, energy penalty, technology scale-up, diverse options, permitting
- Point-source capture
  - Load-following operation and low utilization factors
  - Plant integration / unit characteristics
- Direct air capture
  - Cost and complexity due to low concentration of CO_2
- Bioenergy with CCS / natural systems
  - Source, transportation and technology

CO_2 Concentrations by Source

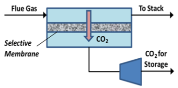




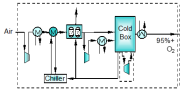
Absorption



Adsorption



Membranes



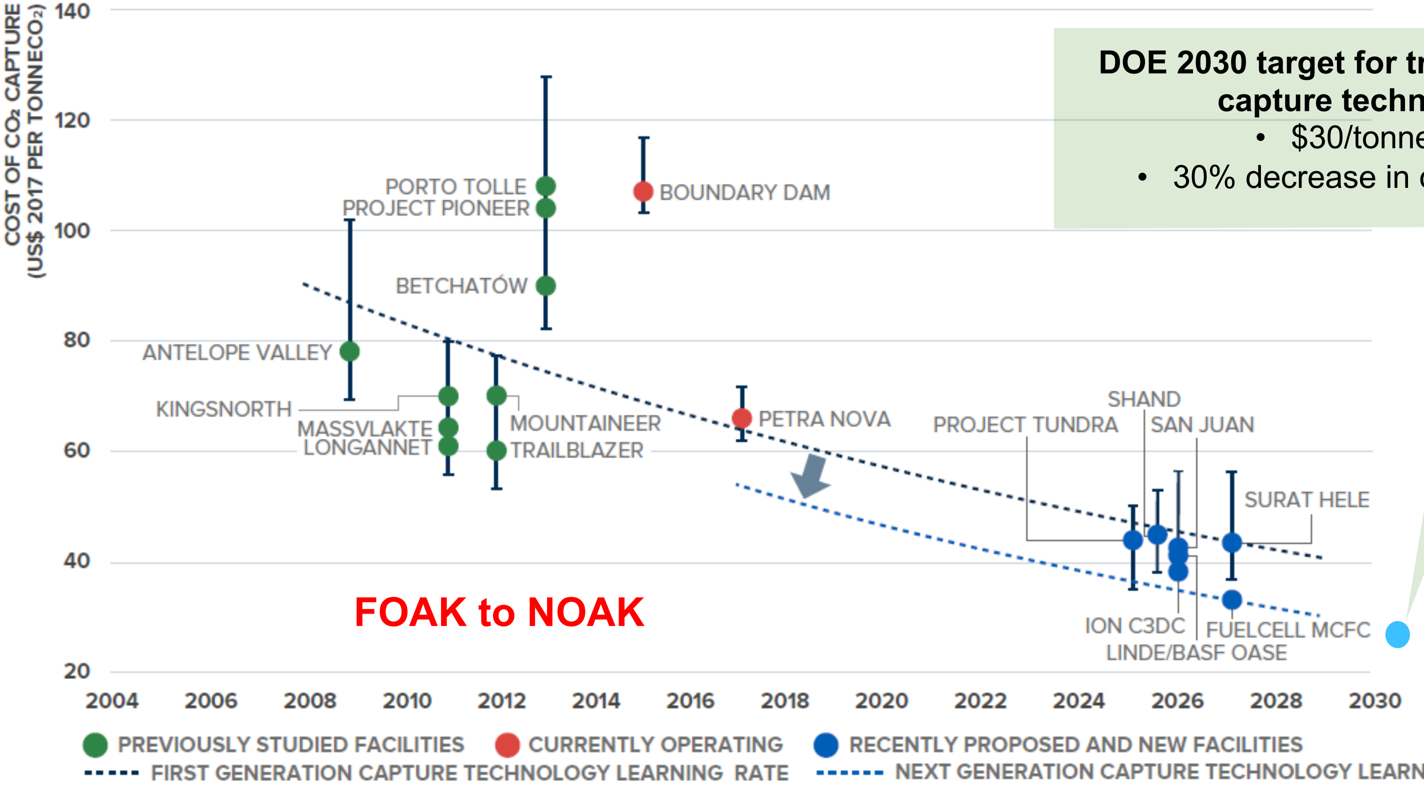
Cryogenics

Source: EPRI

Carbon capture is essentially a challenge of separation

Increase process efficiency → Minimize energy
Reduce equipment size → Minimize capital cost

Current Capture Cost Reduction Expectations



DOE 2030 target for transformational capture technologies

- $30/tonne CO_2
- 30% decrease in cost of energy

Source: Global CCS Institute, Global Status of CCS, 2019

Impact of 45Q Tax Credits: Electric Power Industry

The revised 45Q tax credits are motivating electric power companies (and other investors) to reexamine business models for CCS. The companies are evaluating:

- Value of the tax credit compared to the costs of CCS
- Business models and ability to monetize the 45Q tax credits
- Understand how the tax credit changes power plant dispatch and revenues

Esposito, R.A., Kuuskraa, V.A., Rossman, C.G., Corser, M.M., 2019, Reconsidering CCS in the US fossil-fuel fired electricity industry under section 45Q tax credits; Greenhouse Gas Science & Technology, 0:1–14 (2019); DOI: 10.1002/ghg.1925

CCS Business Models

Four CCS business models are available to an electricity company and its electricity generation units (EGUs).

1. Vertically Integrated Business Model – “Doing it all by yourself”
2. Third-Party Business Model – “Let someone else do it”
3. Joint Venture Business Model – “Let’s do it together” (particularly with a CO_2 EOR operator or saline geology transport and storage operator)

Esposito, R. A., L. S. Monroe, and J. S. Friedman, "Deployment Models for Commercialized Carbon Capture and Storage," Environmental Science & Technology, 2011, 45 (1), 139-146.

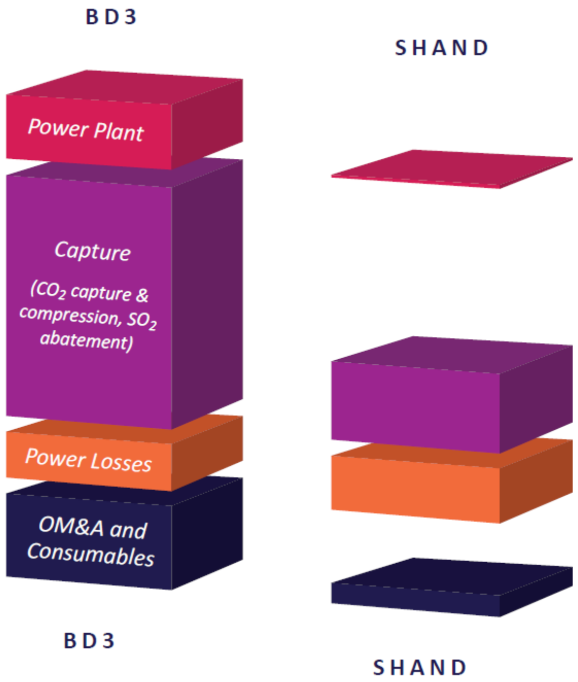
Evaluating Cost-Effectiveness of CO_2 Capture

The following example provides a “recipe” (methodology) for evaluating the cost-effectiveness of installing CO_2 capture equipment at an EGU.

1. First, calculate the additional fuel and operating costs of CO_2 capture
2. Second, recognize that 45Q tax credits significantly reduce net incremental cost of operating the EGU
3. Next, estimate increase in net revenues recognizing the unit will likely operate at availability
4. Fourth, estimate the capital cost for installing CO_2 capture, transport and a geologic storage complex.
5. Finally, compare the NPV of additional net revenues with the capital cost of installing CO_2 capture, transport and storage.

Capital Costs for Retrofitting Coal-Fueled Power Plant with CO_2 Capture

Cost of BD3 and Shand CCS Facilities



- The most recent, publicly available information on adding capture to an existing coal-fueled plant is the engineering study for adding post-combustion CO_2 capture to SaskPower's Shand Power Station.
- The significantly reduced capital costs per MWh of capacity at Shand compared to Boundary Dam (BD3) result from:
  - Construction at larger scale using extensive modularization
  - Improved integration of capture facility with the power unit
  - Incorporating lessons learned from building and operating BD3

Source: Summary for Decision Makers on Second Generation CCS, Based on the Shand CCS Feasibility Study, International CCS Knowledge Centre, ccsknowledge.com.

Capital Costs for Retrofitting Coal-Fueled Power Plant with CO_2 Capture

Drawing on the Shand CCS feasibility study and a similar study by CO2CRC in Australia, and after adjusting for plant size and US dollars, the capital costs (TASC) for retrofitting a 400 MW coal-fueled power plant with CO_2 capture range from $1.1 to $1.2 billion.

	Shand CCS Feasibility Study [1]		CO2CRC 2017 Study [2]	
	Canada	U.S.	Australia	U.S.
Net Power Output (MW)	**270**	**400**	**450**	**400**
	($CAN)	**($U.S.)**	**($AUS)**	**($U.S.)**
Plant Costs				
▪ Direct (million)	$786	$877	-	-
▪ **TASC (million)**	**$986**	**$1,100**	**$1,850**	**$1,200**

*$1US equals $1.34 Canadian; **$1 US equals $1.41 Australian.

1. Summary for Decision Makers on Second Generation CCS, Based on the Shand CCS Feasibility Study, International CCS Knowledge Centre, ccsknowledge.com.
2. CO2CRC (2017). Retrofitting CCS to Coal: Enhancing Australia's Energy Security.

Illustrative Retrofit Coal-Fueled Unit: With and Without CO_2 Capture

*A similar exercise for a natural gas-fueled EGU shows EGU would have a net annual revenue margin $40 million per year higher than without CO_2 capture.	Coal-Fueled EGU	
	No Capture	Capture with $50/tonne value
Heat Rate (MMBtu/MWh)	10	13
Cost of Fuel ($/MWh)	20	26
Variable O&M ($/MWh)	5	6
Total Incremental Cost ($/MWh)	25	32
CO_2 Capture (tonne/MWh)	-	1.09
Value of Captured CO_2 ($/MWh)	-	54
Value of Electricity When Generating ($/MWh)	30	25
Net Margin When Generating ($/MWh)	5	47
Generation of Electricity (MM MWh/yr)	2	3
Net Revenue Margin (million $ / yr)	10	140
Change in net annual margin relative to No Capture (million $ / yr)		+130

- Installation of CO_2 capture increases incremental power generation cost of the EGU from $25/MWh to $32/MWh
- With a CO_2 emission rate of 1.09 mt of CO_2 per MWh and a $50 mt 45Q “bounty” for capturing and storing CO_2 in a geologic formation, the EGU receives $54/MWh, making its incremental cost of producing electricity negative
- With negative net costs per MWh, the EGU would operate at availability, here 3 million MWh per year versus 2 million MWh per year without CO_2 capture
- The EGU now has a net annual revenue margin of $140 million, $130 million per year higher than without CO_2 capture*

Capital Costs for Adding CO_2 Capture to a New NGCC Plant

Drawing on prior DOE/NETL and GCCSI studies and after adjusting for plant size and 2019 dollars, the capital costs (TASC) for adding CO_2 capture to a new 400 MW NGCC plant range from $420 to $430 million.

	U.S. DOE/NETL (2013) [11]				GCCSI (2017) [12]			
CO2 Capture	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Gross	640	600			640	600		
Net Power Output (MW)	630	560	560	400	630	560	560	400
			▲ Cost (2011$)	▲ Cost (2019$)			▲ Cost (2015$)	▲ Cost (2019$)
Plant Costs								
▪ Direct (million)	$430	$830	+$400	+$320	$430	$860	+$430	+$330
▪ **TASC (million)*****	**$570**	**$1,090**	**+$520**	**+$420**	**$560**	**$1,120**	**+$560**	**+$430**

* Mid-2019/2011$ = 1.12; **Mid-2019$/2015$ = 1.08

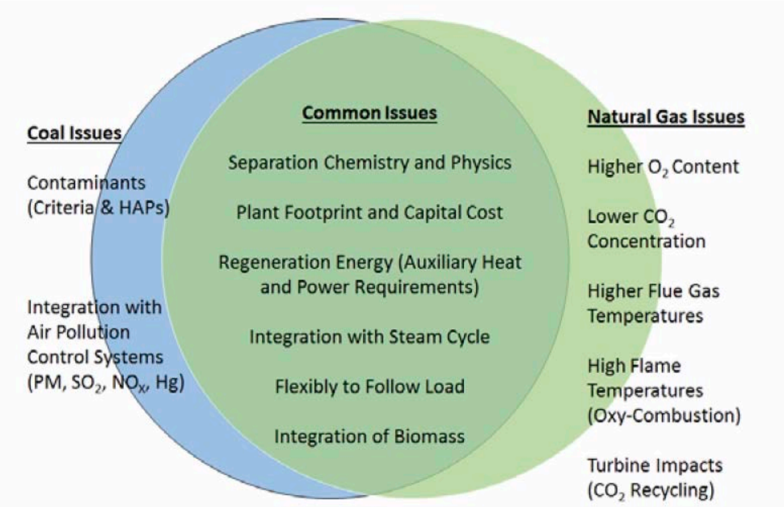
***Assuming owner and financing costs of 30% for U.S. DOE/NETL and GCCSI studies.

11. Department of Energy/National Energy Technology Laboratory. (2015). Cost and Performance Baseline for Fossil Energy Plants, Volume 1, Rev. 3.
12. Global CCS Institute (2017). Global Costs of Carbon Capture and Storage: 2017 Update.

Capital Cost Comparison of Coal and NGCC

For coal vs. natural gas, here are the main points in the capital cost comparison considered in the analysis.

- NGCC is less carbon intensive due to its higher efficiency so less CO_2 to capture and compress
- Much greater CO_2 to be compressed in a SCPC-coal system than in NGCC making the compressors and drying BEC 2.5X greater for those components
- NGCC has a lower raw water consumption rate (fewer cooling water pumps); cooling towers are sized ~2X larger for SCPC coal
- NGCC requires a smaller stripper tower (less solvents) as compared to SCPC-coal but a larger absorber tower. Solvent makeup is lower in NGCC as related to both degradation and slip.
- NGCC would not require polishing scrubbers to reduce SO_2
- **BEC of the CO_2 removal system for NGCC is lower than for SCPC-coal**



Source: DOE, Carbon Capture Opportunities for Natural Gas Fired Power Systems, 2017

Capital Costs for Establishing Storage Site

	Total Cost (millions)
A. Site Design	
1. Site Characterization and Modeling	$8.4
▪ Drill Characterization Wells	
▪ Purchase and Interpret 2-D Seismic	
▪ Build Geologic Model	
▪ Conduct Reservoir/Geophysical Modeling	
2. Class VI Permit Application	$0.6
3. MRV Plan for Subpart RR	$0.1
4. Financial Bonds	$0.2
5. Site Preparation (included in well costs)	-
6. Acquisition of Pore Space Rights (assumed available)	-
Sub-Total	**$9.3**
B. Site Installation	
1. CO2 Injection Wells	$14.3
2. Monitoring Wells	$20.0
3. Seismic/Microseismic	$2.1
4. Transportation	$7.4
5. Other Costs/Contingency	$7.4
Sub-Total	**$51.2**
C. Total	**$60.5**

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- The capital costs for characterizing and installing the CO_2 storage complex at this high-quality storage complex are $60.5 MM
- Less geologically favorable, smaller and more distant CO_2 storage complexes can have capital costs several times higher

Esposito, R.A., Kuuskraa, V.A., Rossman, C.G., Corser, M.M., 2019, Reconsidering CCS in the US fossil-fuel fired electricity industry under section 45Q tax credits; Greenhouse Gas Science & Technology, 0:1–14 (2019); DOI: 10.1002/ghg.1925

Observations and Discussion (Retrofit PC)

Does the 45Q tax credit at $50/tonne make retrofitting an existing 400 MW coal-fueled power plant with CCS cost-effective?

- The discounted **$130 million of increased annual net revenues** from capturing CO_2 (example EGU) equals $1.1 billion, with 12 years of 45Q tax credits
- The capital costs of CO_2 capture and storage (example EGU) range from **$1.2 to $1.3 billion**, placing capital costs higher than discounted net revenues
- The 12-year Section 45Q tax credit would need to be **extended an additional 4 years, to a total of 16 years**, (creating $1.3 billion of discounted net revenues with a 7% discount rate) to make CCS cost-effective in the illustrative example

Observations and Discussion (new NGCC)

Does the 45Q tax credit at $50/tonne make installing CCS on a new 400 MW natural gas-fueled power plant cost-effective?

- The discounted **$40 million of increased annual net revenues** from capturing CO_2 (example EGU) equals $340 million, with 12 years of 45Q tax credits
- The capital costs of adding CO_2 capture and storage to a new natural gas-fueled power plant range from $500 to $510 million, placing capital costs higher than discounted net revenues
- The 12-year Section 45Q tax credit would need to **extend and additional 8 years, to a total of 20 years** (creating $460 million of discounted net revenues at a 7% discount rate) to make CCS cost-effective in the illustrative example

Esposito, R.A., Kuuskraa, V.A., Rossman, C.G., Corser, M.M., 2021, Improving the Business Case for CCS in the Electric Generation Industry Proceedings of the 15th Greenhouse Gas Control Technologies Conference 15-18 March 2021, , Abu Dhabi, UAE, Number of pages: 10 Posted: 02 Apr 2021

Illustrative Retrofit NGCC Unit: With and Without CO_2 Capture

Key Numbers from DOE funded FEED Study	Without capture	With capture
Capacity net of steam and electricity needed for capture (MW)	525	446
Net plant heat rate (Btu/kWh)	6627	7684
Fuel cost ($/MWh)	27	31
Variable O&M ($/MWh)	4	4
Capacity factor	75%	92%
Average value of electricity produced ($/MWh)	30	27
CO2 captured (short tons per day)	0	4886
Value of CO2 capture at $85 per metric ton (million $ per year)	0	125.6
Overnight cost of retrofit (billion $)		0.75
PV of additional fuel, o&m, lost capacity, lost electricity, CO2 transport and storage (billion $)		0.40
PV of net cost of retrofit including cost of capital (billion $)		1.31
Net benefit (billion $)		0.10

Observations and Discussion (retrofit NGCC)

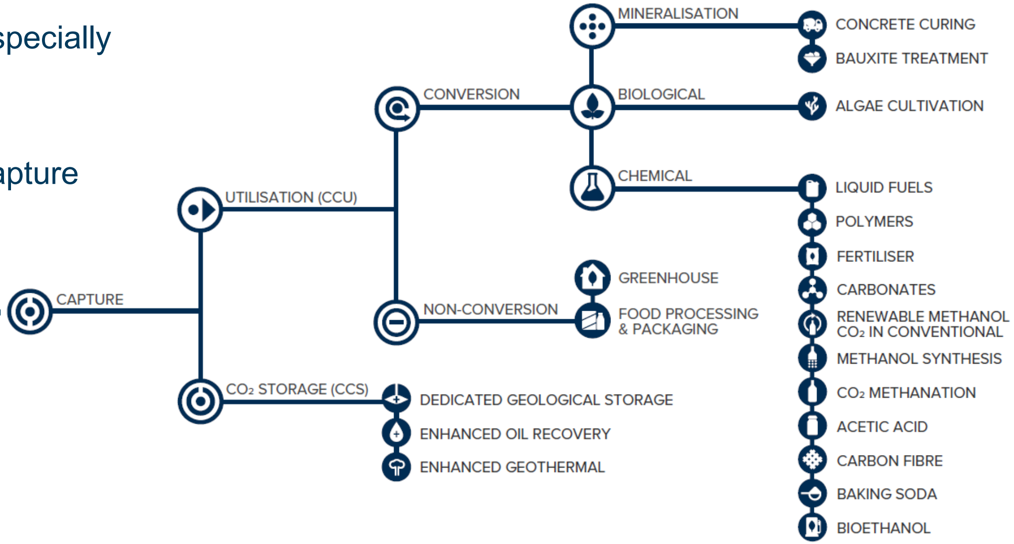
Does the 45Q tax credit at $85/tonne make installing CCS on a retrofit 525 MW natural gas-fueled power plant cost-effective?

- The discounted **net revenues** from capturing CO_2 (example EGU) equals $1.4 billion, with present value of 12 years of capture of 45Q tax credits grossed up for tax rate
- The capital net costs of adding CO_2 capture and storage to the retrofit natural gas-fueled power plant estimated at $1.3 billion, placing capital costs lower then discounted net revenues
- The 12-year Section 45Q tax credit would be enough to cover the costs of discounted net of $100 million to make CCS cost-effective in the illustrative example depending on the uncertainty range of any site-specific FEED study

The cost of CO_2 transportation and storage used here was $8 per tonne.

A Few Additional Thoughts!

- Public awareness and stakeholder acceptance especially with CO_2 pipelines
- Shared CO_2 infrastructure making it feasible to capture CO_2 at smaller industrial facilities
- Use and utilization options
- What happens after 12 years?
- Must have successful projects!
- DOE vs. non-DOE funded path forward?
- CCS must make deep GHG reductions in the utility and industrial sectors over the next 10 years if the tax credit is to be extended.



Source: EPRI

Questions

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