



Solutions for Today | Options for Tomorrow

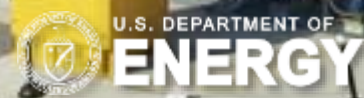
Point Source Carbon Capture



US-Norway Bilateral
November 1, 2023



Ron Munson
Point Source Carbon Capture
Technology Manager
National Energy Technology Laboratory



- **Infrastructure Bill**

- Carbon management provisions.. CCS Demos (FOA 1 and FOA2), Carbon Capture Large Pilots

- **FECM Carbon Capture Program**

- Power & Industrial

Carbon Management BIL Funding

Carbon Transport and Storage

\$2.5B CO2 transportation loan support via CIFIA program

\$100M for CO2 transportation engineering studies

\$2.5B for expanding storage capacity



Carbon Capture & Industrial Decarb

\$2.5B Commercial CCS demo
\$1B CCS pilots

\$8B: H₂ Hubs
\$6B: Industrial Decarbonization

Carbon Dioxide Removal

\$3.5B for DAC Hubs
\$115M for DAC Prizes



Bipartisan Infrastructure Law
Funding Opportunity

Carbon Capture Demonstration
Projects Program



Office: Clean Energy Demonstrations

FOA number: DE-FOA-0002738

[Funding Notice: Bipartisan Infrastructure Law: Carbon Capture Demonstration Projects Program | Department of Energy](#)

FOA 2738 – Selections for award negotiations



	Sector	Fuel	Host Site	Capacity	CO2 Technology
Duke Energy Indiana, LLC	Electricity Generation	Coal/NG	Duke Energy Edwardsport	3.6 MTA CO2	Honeywell, UOP
Entergy Services, LLC	Electricity Generation	NG	Lake Charles Power Station	2.5 MTA CO2	MHI, KS-21
Lehigh Hanson	Cement Production		Mitchell Cement Plant in Mitchell, Indiana	2 MTA CO2	MHI, KS-21
Navajo Transitional Energy Company, LLC (NTEC)	Electricity Generation	Coal	Four Corners Power Plant (FCPP)	10+ MTA CO2	MHI, KS-21
Southern States Energy Board	Cement Production		Ash Grove Foreman Cement Plant, Foreman, Arkansas		Air Liquide's Cryocap™
Taft Carbon Capture, LLC	CHP	NG	Taft cogeneration power plant	3 MTA CO2	Post combustion capture, solvent
Tampa Electric Company	Electricity Generation	NG	Polk Power Station in Mulberry, Florida	3.7 MTA CO2	ION, post combustion capture
University of Illinois at Urbana-Champaign	Electricity Generation	Coal	Dallman 4, PC coal power plant at City Water, Light and Power in Springfield, Illinois	2 MTA CO2	Linde-BASF
MTR	Electricity Generation	Coal	Dry For Power Station, Gillette, Wyoming	2.2 MTA CO2	MTR

Point Source Carbon Capture Portfolio

Components



Testing novel materials & processes with simulated exhaust

Small Pilots



Bench- and Pilot-scale technology testing with real flue gas

Large Pilots



Engineering scale for integrated capture system

Demo



Unit-wide Carbon transport & storage

No storage

ARPA-E



FLECCS



FLECCS

FECM



MTR, UIC, TCM

IEDO



OCED

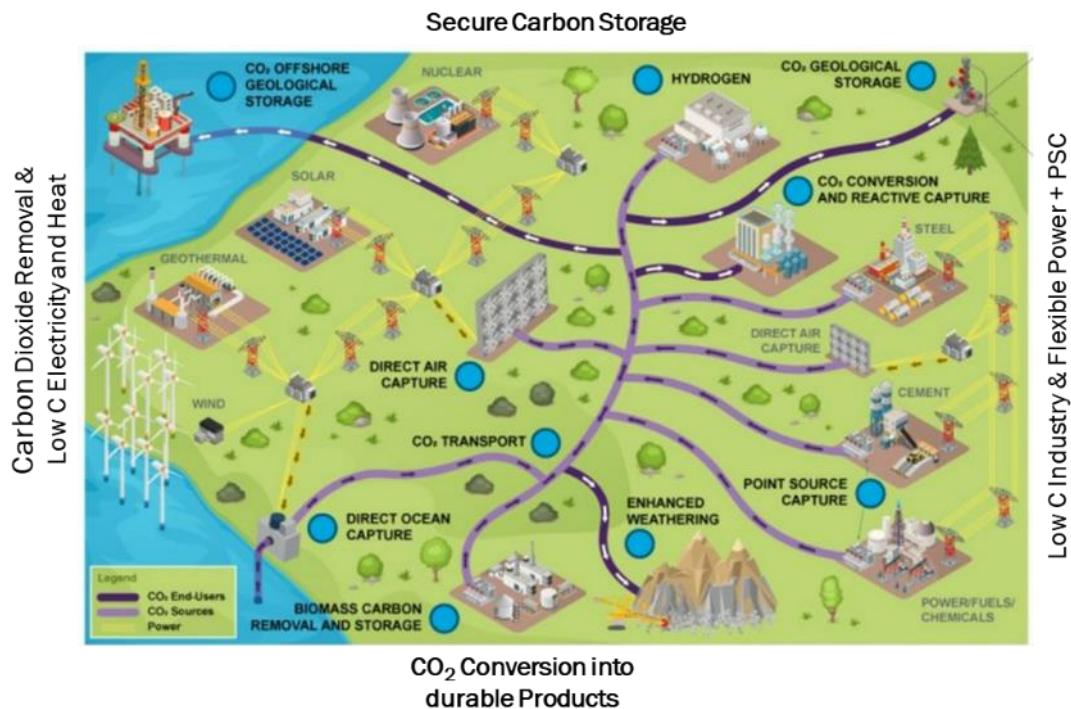
25 MW 75 KTA

BIL Funded

unit 300+ KTA

PSC Strategic Vision

Support demonstrate first-of-a-kind carbon capture on power and industrial sectors coupled to dedicated and reliable carbon storage, that will lead to commercially viable carbon hub opportunities for widescale deployment and facilitate a carbon-free economy by 2050, emphasizing robust analysis of life cycle impacts, and understanding air/water quality impacts.



Focus Area 1: Support Power Retrofit Demos

- Enabling technologies

Focus Area 2: Net Zero, Flex Power

- Technology development to support flexible CCS with high capture efficiency
- FEEDs to seed the formation of Carbon Hubs.

Focus Area 3: Support Industrial Retrofit Demos

- Enabling technologies

Focus Area 4: Integrated decarbonized industrial + CCS

- Technology development for integrated decarbonized industrial processes coupled with transformational CCS
- FEEDs to seed the formation of Carbon Hubs.

Commercial, Licensing Deals

Lafarge Canada Collaborates with Svante and Dimensional Energy to Begin Utilization of CO2 Captured at Richmond Cement Plant

May 15, 2023

Svante

2023 Honoree

Svante Recognized as One of the World's Top 100 Private Deep Tech Companies by XPRIZE | XB100

Svante has been recognized as one of The World's Top 100 Private

READ MORE

Svante | 3M

3M and Svante Announce Joint Development Agreement to Develop and Produce CO2 Removal Products

The companies will work together to identify and deploy projects which can

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ION

SK INC. AND ION CLEAN ENERGY ENTER NEW PARTNERSHIP TO COMMERCIALIZE ION'S INDUSTRY-LEADING CARBON CAPTURE TECHNOLOGY

Honeywell

Honeywell Collaborates With The University Of Texas At Austin For Innovative Carbon Capture And Storage Technology

ExxonMobil

ExxonMobil, Mitsubishi Heavy Industries form carbon capture technology alliance

Schlumberger and RTI

Schlumberger and RTI International Partner to Accelerate the Industrialization of Innovative Carbon Capture Technology

chevron invests in carbon capture and removal technology company, svante

HOUSTON/WANCOUVER, Dec. 15, 2022 - Chevron New Energy (CNE), a division of Chevron U.S.A. Inc., and Svante announced that CNE is the lead investor in Svante's Series L fundraising round, which raised \$100 million that will be used to scale up the commercialization of Svante's carbon capture

SRI International

Baker Hughes acquires exclusive license from SRI International for Mixed Salt Process technology for carbon capture

Baker Hughes

Baker Hughes Acquires Mosaic Materials to Advance Next-Generation Carbon Dioxide Capture Technology

ION

KOCH ENGINEERED SOLUTIONS ANNOUNCES STRATEGIC PARTNERSHIP WITH ION CLEAN ENERGY

KOCH ENGINEERED SOLUTIONS

December 16, 2022

Technip Energies and Shell Catalysts & Technologies Strengthen Strategic Alliance on CANSOLV Technology to Address Growing Carbon Capture and Storage Demand

Linde Signs Agreement with ExxonMobil for Carbon Dioxide Off-Take

GE and Svante Announce Collaboration to Develop Carbon Capture Technology for Power Generation

Baker Hughes

Baker Hughes Partners with NET Power Zero-Emissions Power Plants

CHART

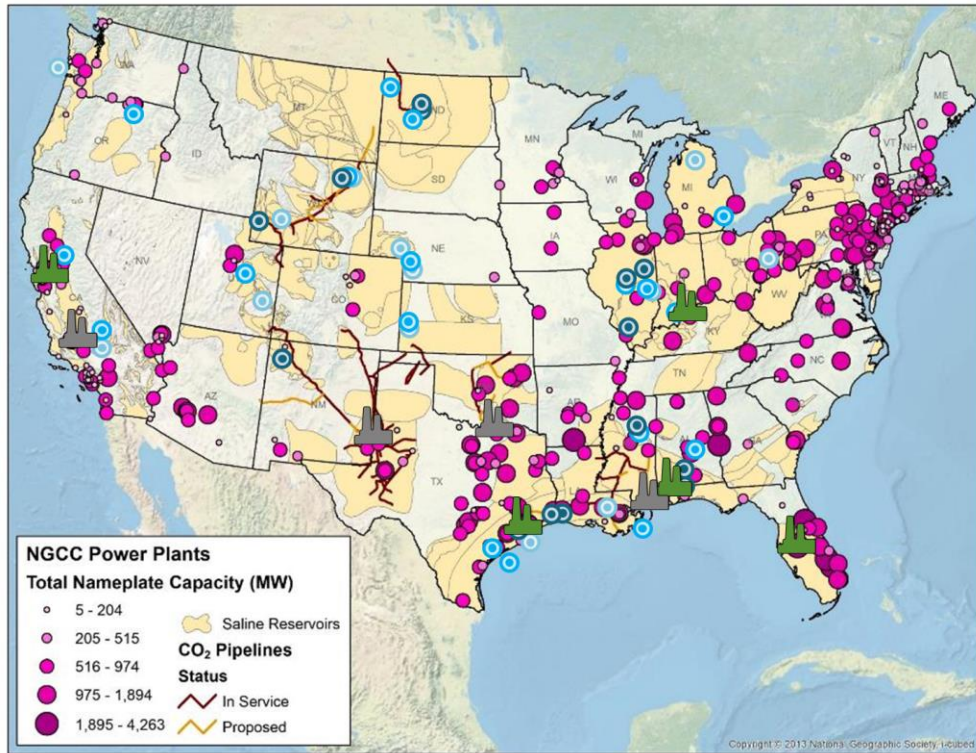
Chart Industries Acquires Sustainable Energy Solutions, Inc.

Exxon Mobil buys Denbury, pipeline company with carbon capture expertise, for \$5 billion

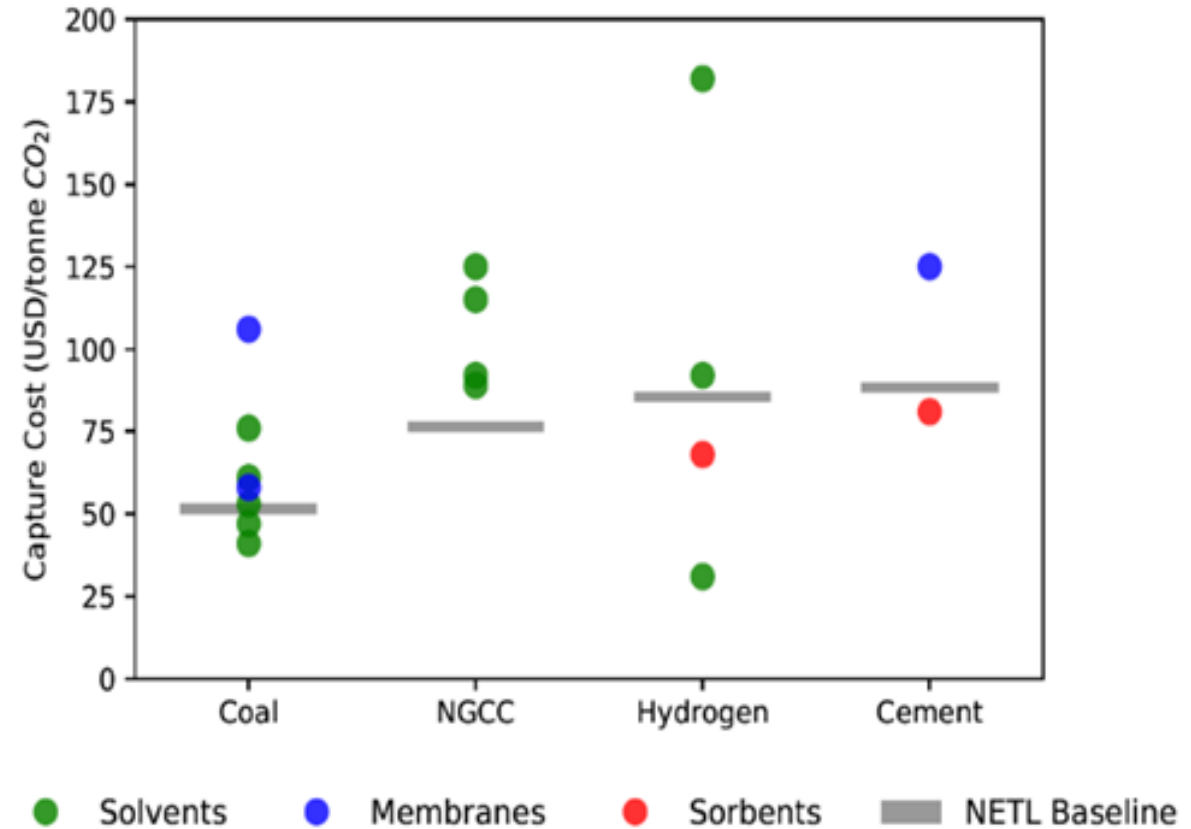
LG&E and KU, EPRI, University of Kentucky, begin industry-leading research

NGCC FEEDs

NG FEEDs



FEEDs vs. NETL Baseline



CCS FEEDS for Cement Plants

Pre-FEEDs



LafargeHolcim Cement Plant
Florence, CO



Balcones Cement Plant,
New Braunfels, TX

1 MTA CO₂

MTR's Polaris membrane



FEEDs



Holcim Ste. Genevieve
Cement Plant
Bloomsdale, Missouri

2.9 MTA CO₂

Air Liquide' Cryocap FG



Balcones Cement Plant,
New Braunfels, TX

1.6 MTA CO₂

RTI's Non-Aqueous Solvent



Mitchell Cement Plant
Mitchell, IN

2 MTA CO₂

MHI's KS-21



Ash Grove Foreman
Foreman, AR

Air Liquide' Cryocap FG



Project Enterprise (ION) 1 MW



- 10 tpd CO₂ pilot on a 1 MWe slipstream flue gas
- NGCC power plant, Calpine's Los Medanos Energy Center, CA
- MEA, ICE-21 and ICE 31 solvents testing
- ✓ System Commissioned and ready for use



Chevron Natural Gas Carbon Capture Technology Testing Project

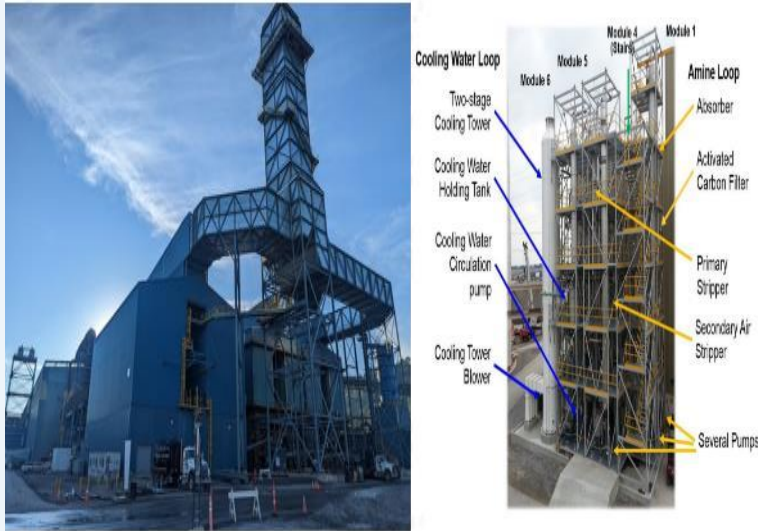
25 tpd CO₂



- Chevron's Kern River oil field San Joaquin Valley, CA USA
- Skid-mounted modular design of second-of-a-kind (SOAK) Svante capture plant
- ✓ Full site commissioning completed
- ✓ Plant Start-up and Ramp-up completed
- Operation of the 14% CO₂ Flue Gas: testing in progress



Uky/Nucor Pilot Carbon Capture 3 tonne/day



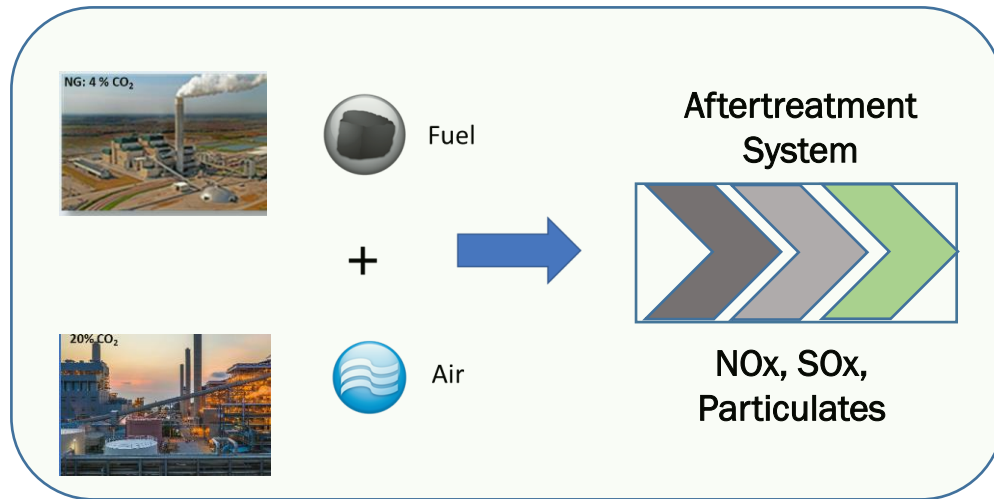
- Nucor Steel Gallatin Plant – Electric Arc Furnace
- 1.5% CO₂ flue gas
- High O₂ content – potential for solvent degradation
- Advanced process control strategy maintains 95% capture efficiency despite variable flue gas concentration
- Under construction

SES/Chart Cryogenic Carbon Capture from Cement Production 30 tonne/day

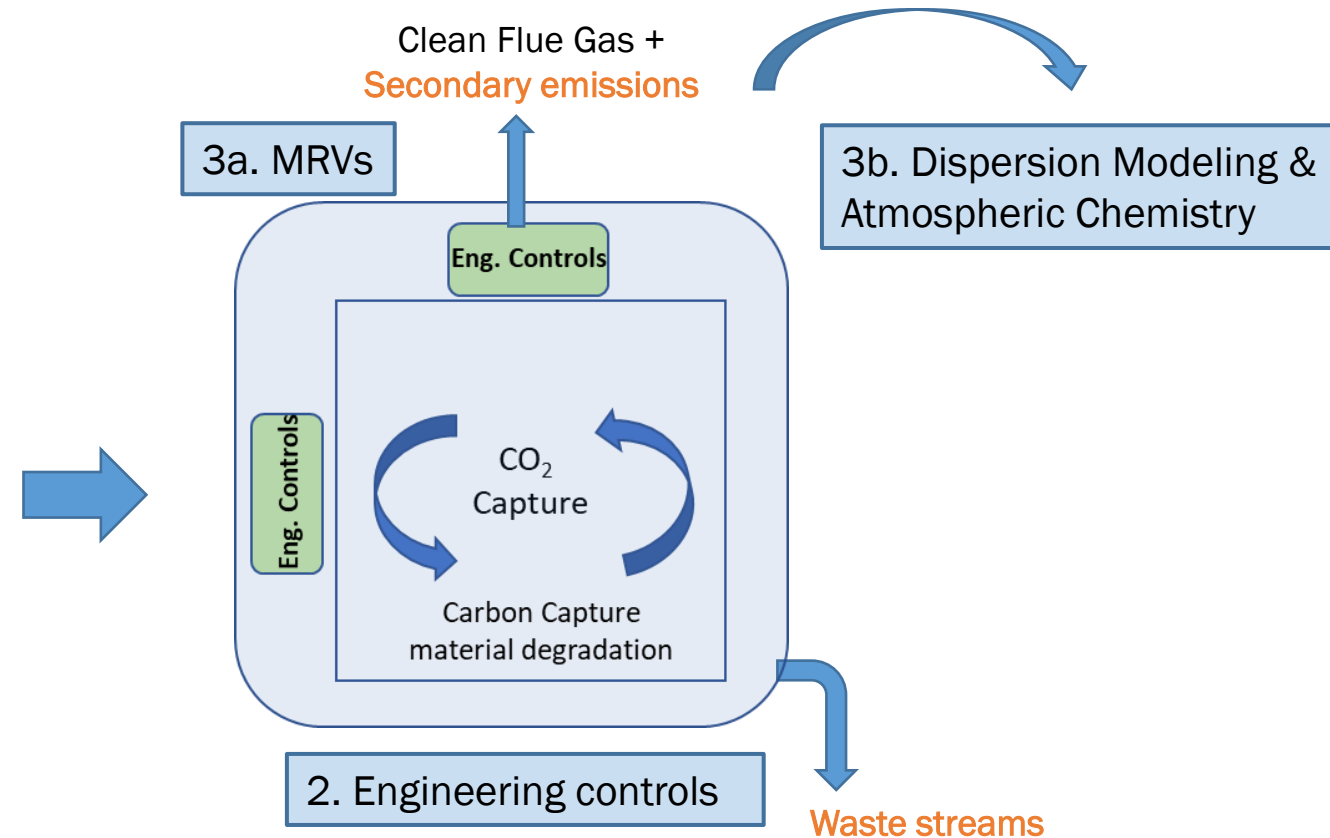


- Sugar Creek Cement Plant, Missouri
- Skid-based design for easy retrofit with limited integration
- Water recovery
- Requires only electricity
- Co-removal of NO_x, SO_x, and other pollutants
- CO₂ compression occurs as a liquid, reducing cost and energy demand

Measurement, Monitoring and Controlling Potential Environmental Impacts from the Installation of Point Source Capture

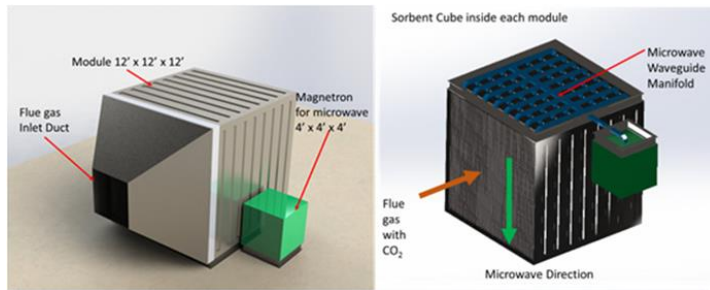


1. Impact of fuel, duty cycle, aftertreatment operation



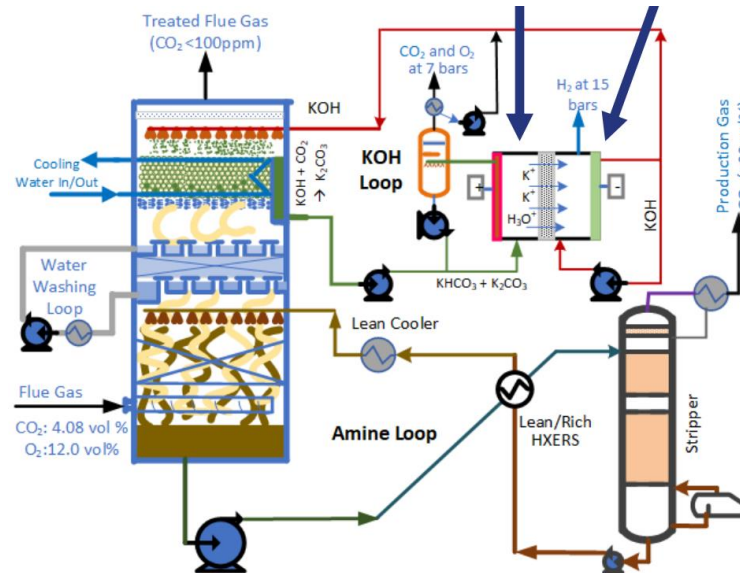
2. Engineering controls

Highly Efficient Carbon Capture



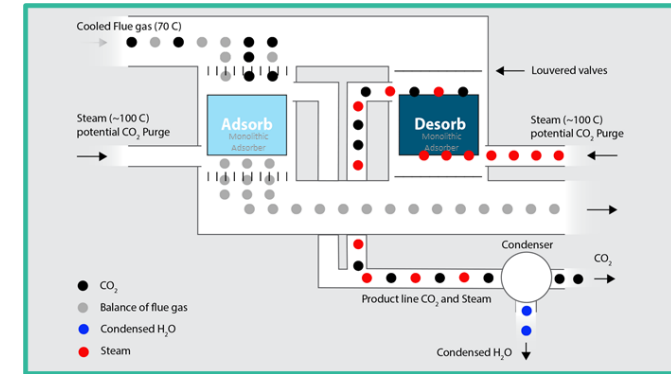
Polymer sorbent-based microwave assisted thermal swing adsorption (MTSA) process

[Project Landing Page | netl.doe.gov](http://netl.doe.gov)



Dual-loop solution process: Amine & Electrochemical Polishing

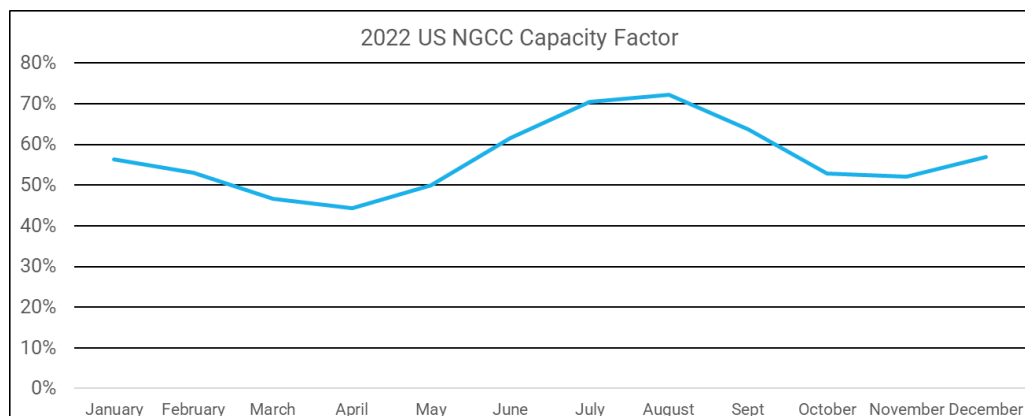
[Project Landing Page | netl.doe.gov](http://netl.doe.gov)



Polyethyleneimine Monolith Carbon Capture Process

[Project Landing Page | netl.doe.gov](http://netl.doe.gov)






Flexible Operations – ARPA-E FLECCS



“In 2019, the average number of starts for combined cycle plants was 39 per year. Just three years later, it's likely to hit 70, and the average could break 100 by 2023.”

Power Magazine, Aug 1, 2022

Technology teams

	NGCC CCS integrated with DAC using novel contactor
	Low-water solvent and rotating packed bed contactor
	Active transport ceramic membrane integrated into HRSG
	Novel sorbent with integrated storage/regeneration
	Novel solvent with proprietary adsorber

PSC Power: What's Next

Focus Area 1: Support Power Retrofit Demos

- Enabling technologies

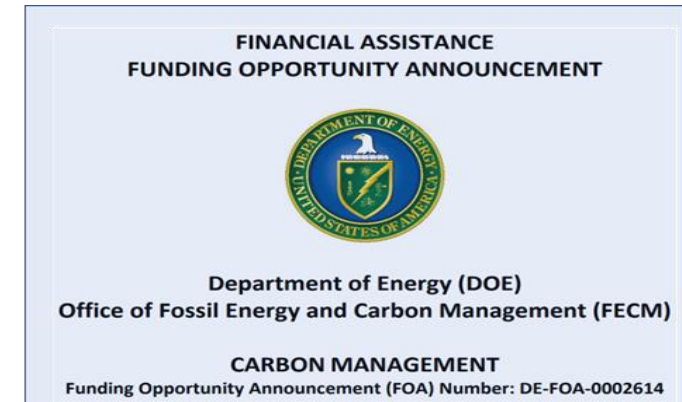
Focus Area 2: Net Zero, Flex Power

- Technology development to support flexible CCS with high capture efficiency
- FEEDs to seed the formation of Carbon Hubs.

FOA 2614 Round 3: Reviewing applications

AOI 3B: *Front-End Engineering Design Studies for Carbon Capture Systems at Existing (Retrofit) Domestic Natural Gas Combined Cycle (NGCC) Power Plants*

AOI 3C: *Engineering-Scale Testing of Transformational Carbon Capture Technologies for Natural Gas Combined Cycle (NGCC) Power Plants*



AOI-1. Carbon Conversion Technology

The objective of AOI-1 is to support R&D investigating the conversion of carbon dioxide (CO₂) into environmentally responsible and economically feasible products.

AOI-2. Carbon Dioxide Removal Technology

The objective of AOI-2 is to solicit applications that develop carbon dioxide removal (CDR) technologies (e.g., direct air capture with durable storage, biomass carbon removal and storage, enhanced mineralization, ocean-based CDR, terrestrial sequestration) to support progress towards achieving the U.S. Department of Energy's Carbon Negative Shot target

AOI-3. Point Source Carbon Capture

The objective of AOI-3 is to solicit applications that are specifically focused on developing lower cost, highly-efficient, technologies for point source capture from fossil fuel power plants and industrial point sources.

AOI-4. Carbon Storage Technology

AOI-4 aims to support resource assessments to securely store large amounts of CO₂.

PSC Industrial: What's Next

Focus Area 3: Support Industrial Retrofit Demos

- Enabling technologies

Focus Area 4: Integrated decarbonized industrial + CCS

- Technology development for integrated decarbonized industrial processes coupled with transformational CCS
- FEEDs to seed the formation of Carbon Hubs.



AOI-3 Point Source Carbon Capture

The objective of AOI-3 is to solicit applications that are specifically focused on developing lower cost, highly-efficient, technologies for point source carbon capture from fossil fuel power plants and industrial point sources capturing CO₂ with over 95% efficiency.

FOA 2614 Round 3: Reviewing applications

AOI 3A: Industrial Pilots - Test transformational, carbon capture technologies under real flue gas conditions from process streams at an industrial facility

- ✓ 95% or greater carbon capture efficiency/95% CO₂ purity.
- ✓ Industrial sectors of interest : (i) chemical production (e.g., petrochemicals) excluding ethanol, ammonia and hydrogen production, (ii) mineral production (e.g., cement and lime), (iii) pulp and paper production, (iv) iron and steel production, (v) glass production, and (vi) oil refining (e.g., catalytic cracker, hydrocracking), excluding steam methane reforming for hydrogen production and natural gas processing.
- ✓ design capacity to capture a minimum of 3 tonne CO₂/day.

FOA 2614 Round 4: Released 9/21/2023

AOI 3D: Decarbonization of Industrial Processes Using Oxygen-Based (Oxy-combustion and Chemical Looping) Approaches

- ✓ *Conceptual design studies followed by a laboratory validation of cost-effective processes for employing oxygen-based approaches (i.e., oxy-combustion, chemical looping) that lead to reductions in CO₂ emissions associated with industrial production processes.*
- ✓ *Phased approach is currently planned with a competitive down-select between Phase 1 (Conceptual Design and Feasibility) and Phase 2 (Continuous Lab-Scale Validation)*
 - ✓ Only entities that receive a Phase 1 award will be permitted to submit a Phase 2 renewal application for consideration.

Carbon Capture Program: Outreach



HIGHLIGHTS

The newsletter is compiled by the National Energy Technology Laboratory to provide information on recent activities and publications related to carbon capture.

To subscribe, click here.

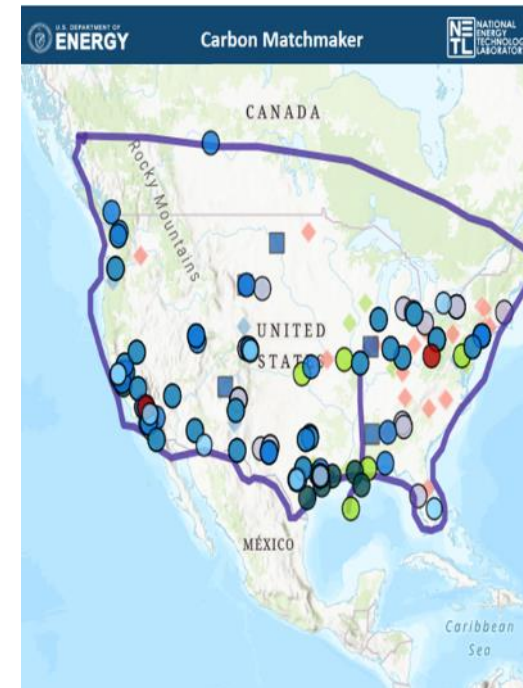
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DOE Announces Funding to Deploy Infrastructure Necessary to Manage and Store Carbon Emissions

The U.S. Department of Energy (DOE) released three funding opportunity announcements (FOA) to border investments in the carbon management industry and to significantly reduce carbon dioxide (CO₂) emissions released into the atmosphere through power generation and industrial operations. The funding from President Biden's Bipartisan Infrastructure Law (BIL) will support three programs to help drive the demonstration and deployment of carbon capture systems, along with carbon transport and storage infrastructure. Carbon Storage Validation and Testing supports the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative and provides up to \$2.25 billion to support the development of new and expanded large-scale, commercial carbon storage projects with capacities to store 50 or more million metric tons of CO₂, along with associated CO₂ transport infrastructure. The Carbon Capture Demonstration Projects Program provides up to \$2.54 billion to develop six integrated carbon capture, transport, and storage demonstration projects that can be readily replicated and deployed at fossil energy power plants and major industrial sources of CO₂. Carbon Dioxide Transport Engineering and Design provides up to \$300 million to design regional CO₂ pipeline networks to safely transport captured CO₂ from key sources to centralized locations.



Carbon Capture Program R&D Compendium



Carbon Matchmaker



Commercial Liftoff Report

[Pathways to Commercial Liftoff: Carbon Management \(energy.gov\)](https://www.energy.gov/pathways-to-commercial-liftoff-carbon-management)

<https://www.netl.doe.gov/carbon-management/carbon-capture>

<https://www.energy.gov/fecm/carbon-matchmaker>

Questions

<http://www.netl.doe.gov/research/coal/carbon-capture>

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