



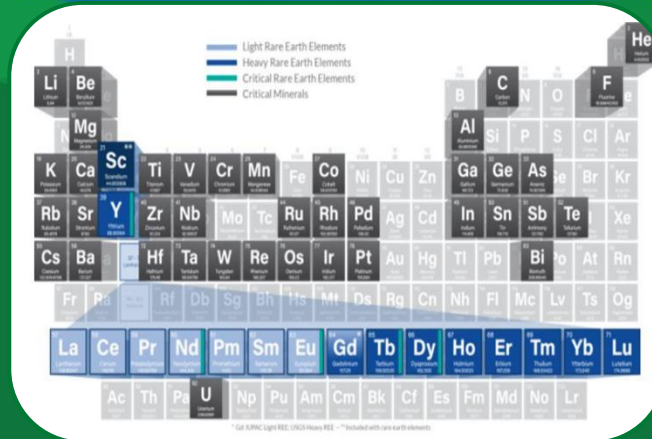
U.S. DEPARTMENT OF
ENERGY

Fossil Energy and
Carbon Management

CO₂ Transport RD&D at the US Department of Energy

Sarah Leung, Carbon Transport Program Manager

DOT PHMSA Public Meeting
Houston, TX | December 14, 2022



Industrial Ecosystem for CCUS and FECM Programs

[Interactive Diagram: https://www.energy.gov/fecm/interactive-diagram-carbon-management-provisions](https://www.energy.gov/fecm/interactive-diagram-carbon-management-provisions)



[Carbon Matchmaker: https://www.energy.gov/fecm/carbon-matchmaker](https://www.energy.gov/fecm/carbon-matchmaker)



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Fossil Energy and
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Fossil Energy and Carbon Management (FECM)

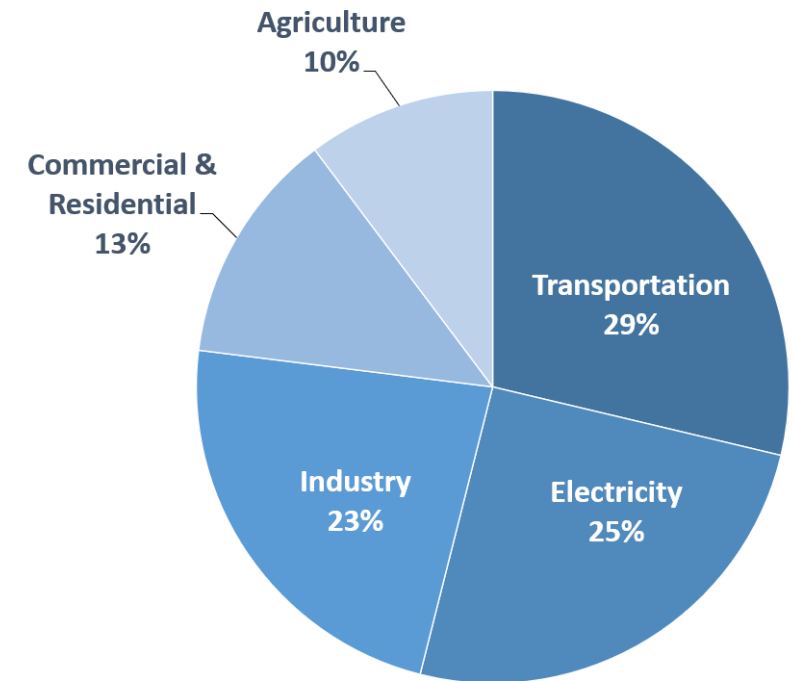
Office of Fossil Energy and Carbon Management

DOE-FE is now DOE-FECM

New name for our office reflects our new vision

- President Biden's goals (*Executive Order 14008*):
 - 50-52% emissions reduction by 2030
 - CO₂ emissions-free power sector by 2035
 - Net zero emissions economy by no later than 2050

Total U.S. Greenhouse Gas Emissions
by Economic Sector in 2019



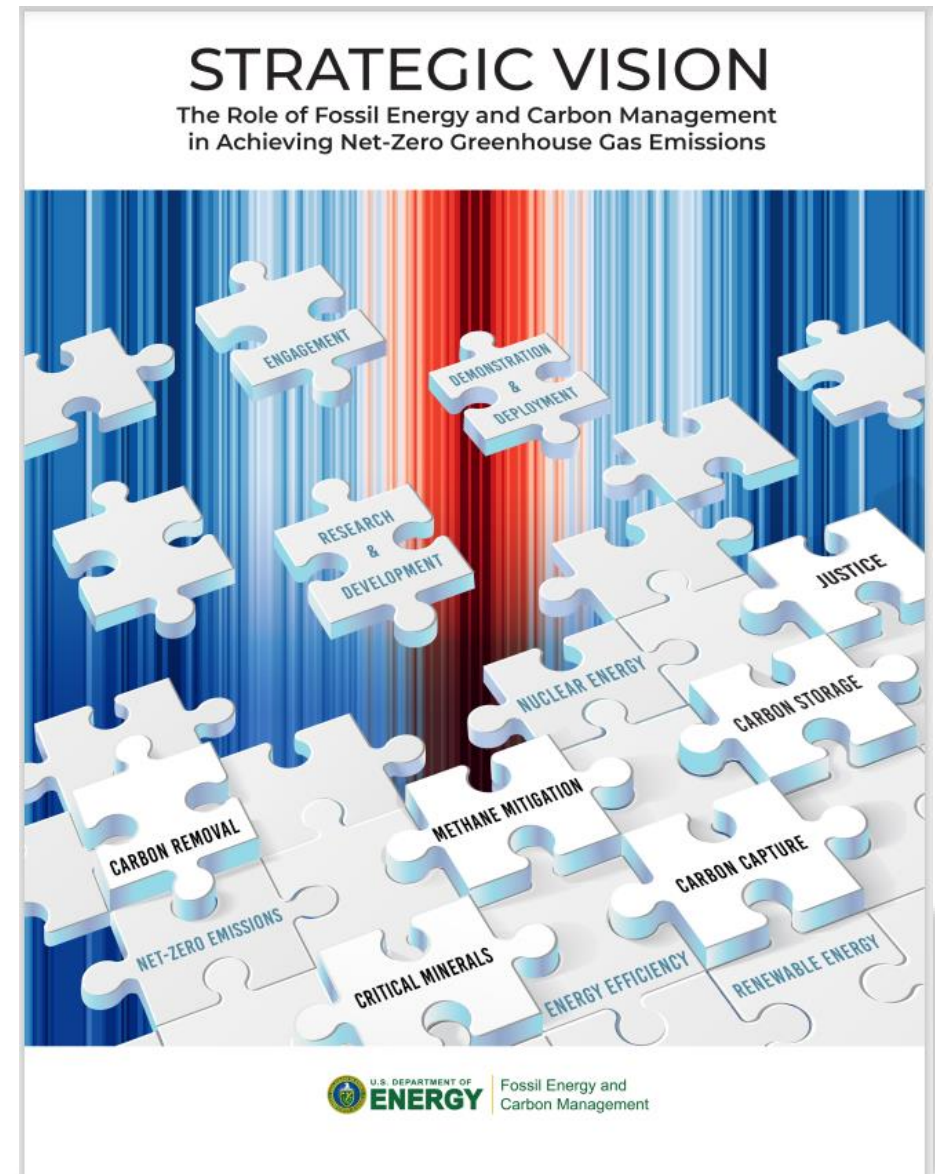
U.S. Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019

FECM Strategic Vision

Released April 5, 2022

Federally-funded RD&D to enable energy innovation and carbon management commercialization

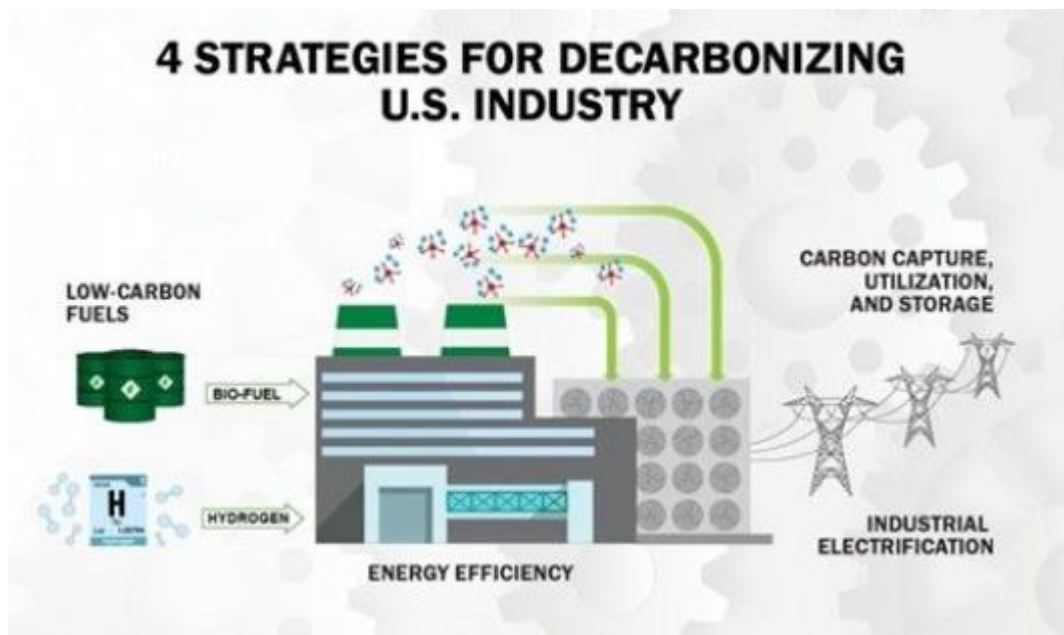
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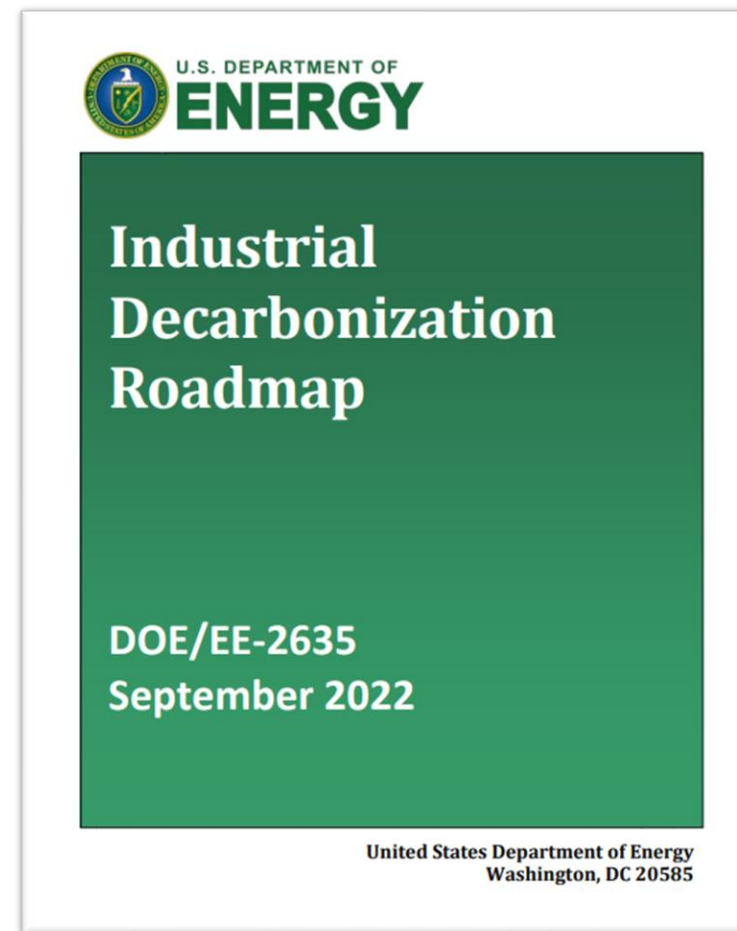
<https://www.energy.gov/fecm/strategic-vision-role-fecm-achieving-net-zero-greenhouse-gas-emissions>

Industrial Decarbonization Roadmap

Carbon Capture, Utilization, and Storage is one of four strategies for decarbonizing US Industry.

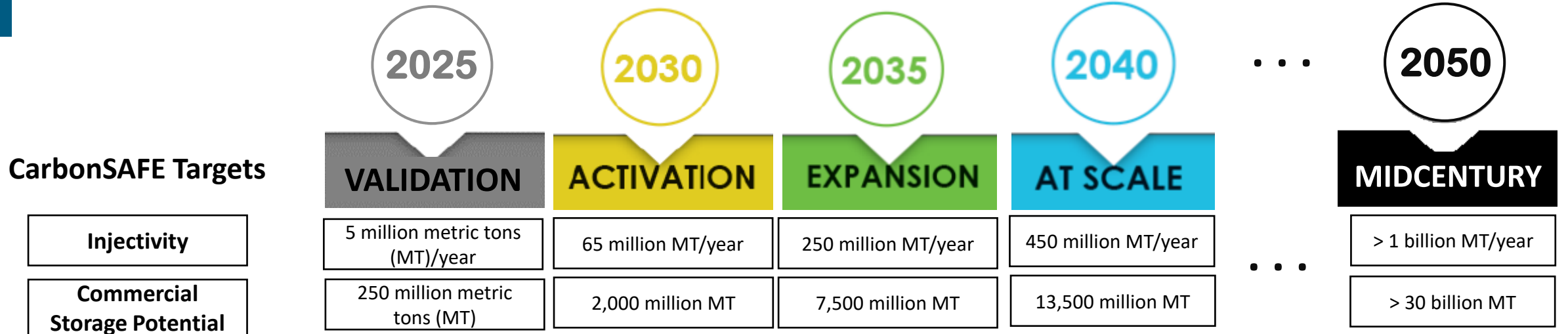


- Iron and Steel Manufacturing
- Chemical Manufacturing
- Food and Beverage Manufacturing
- Petroleum Refining
- Cement Manufacturing



<https://www.energy.gov/sites/default/files/2022-09/Industrial%20Decarbonization%20Roadmap.pdf>

Rapid CCUS and CDR Industry Growth Needed for Achieving U.S. Decarbonization Goals



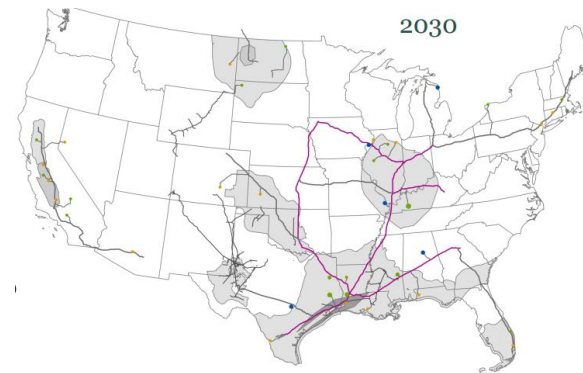
CO2 Transport Modeling

Today: 5,300 miles of pipelines



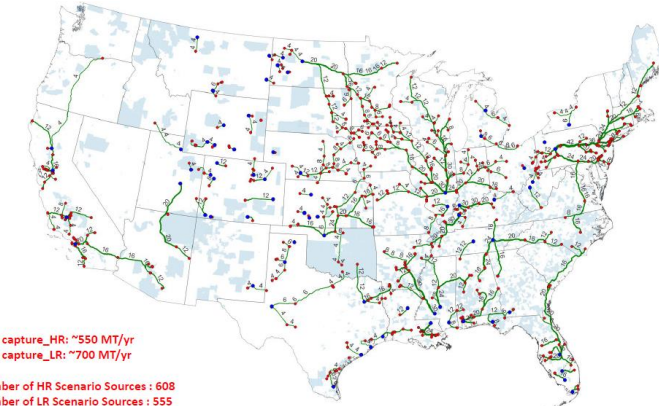
NPC: Meeting the Dual Challenge (2019)

2030: 11,000+ miles of pipelines



Modeling from Princeton's Net-Zero America Study (2020)

2050: 25,000+ miles of pipelines

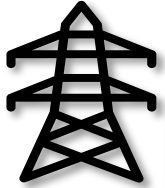


Modeling from Los Alamos National Laboratory (2022)

FECM Strategic Vision: Strategies and Research Priorities for CO₂ Transport & Storage

		5 Year Goal 2030 ACTIVATION	10 Year Goal 2035 EXPANSION	15 Year Goal 2040 AT SCALE
Carbon-SAFE	Commercial Storage Capacity	2,000 Million MT over 30 years	7,500 Million MT over 30 years	13,500 Million MT over 30 years
	Injectivity	Injection of 65 Million MT/yr	Injection of 250 Million MT/yr	Injection of 450 Million MT/yr
Contingent Storage Resource		Identify 5,500 Million MT	Identify 6,000 Million MT	Identify 7,500 Million MT
Repurposing Storage Infrastructure		FEED studies for repurposing onshore and offshore infrastructure (depleted oil/gas fields, wells, pipelines, etc.)		
CO₂ Transport Infrastructure		Support design studies of regional infrastructure; feasibility studies of national network	Support pre-FEED studies of trunk lines to interconnect regional hubs	Support development of trunk lines and feeder lines
Advanced R&D		Develop tools for basin-scale management of storage resources Develop and deploy tools to reduce cost, risk and uncertainty in storage projects Establish CarbonSTORE facilities in multiple different geologic settings Integration of Science-informed Machine learning to Accelerate Real Time decisions for Carbon Storage (SMART-CS) and National Risk Assessment Partnership (NRAP) tools into commercial storage applications		
Crosscutting Synergies		Develop programs to provide technical assistance and make information readily available to agencies and stakeholders		

Carbon Transport and Storage RD&D: An Iterative Process towards Deployment

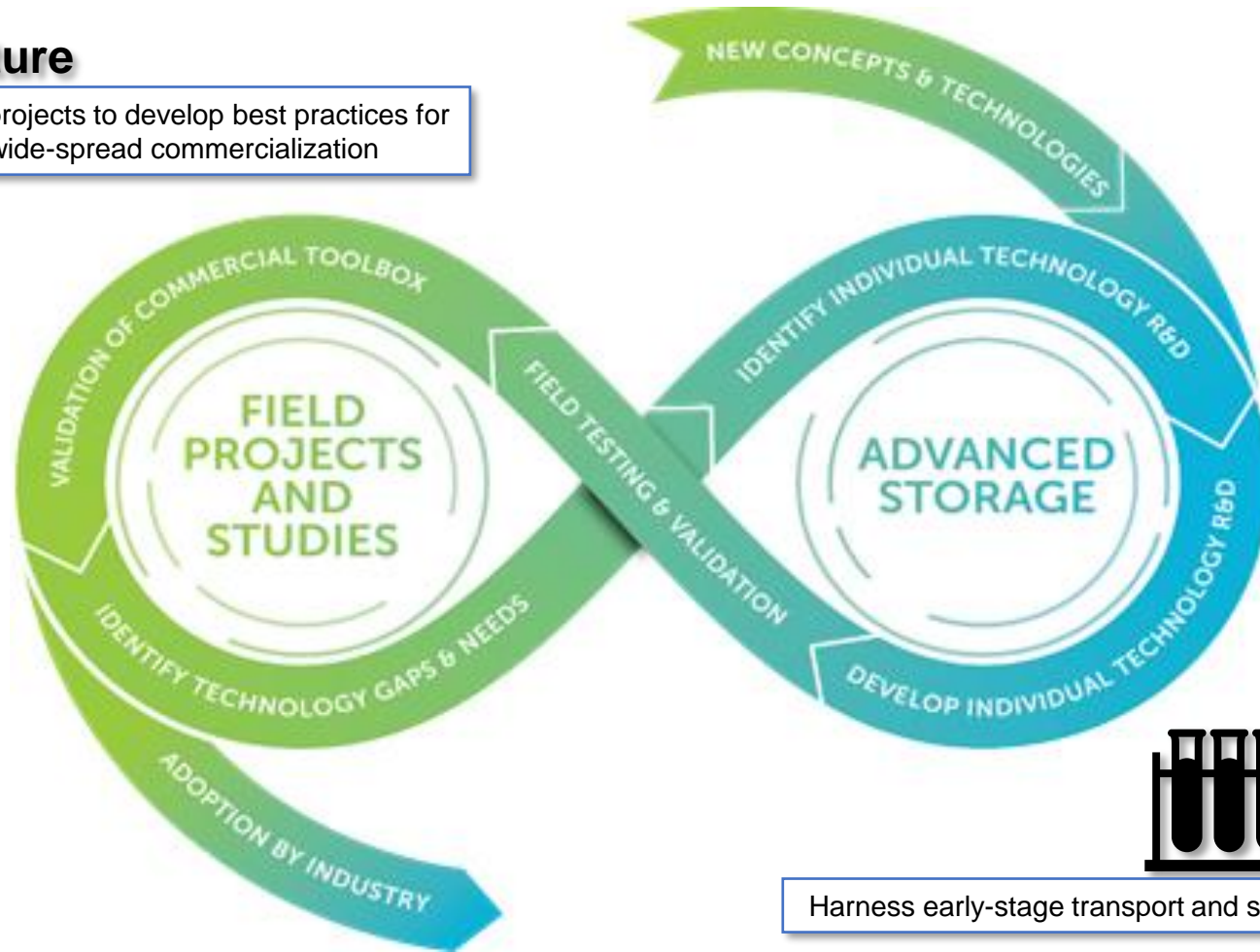


Infrastructure

Large-scale demonstration projects to develop best practices for industry and facilitate wide-spread commercialization

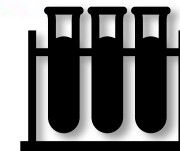
Infrastructure Focus

- Bipartisan Infrastructure Law FOAs
- Carbon Management Hubs
- Offshore CCUS
- Transition of O&G infrastructure



Advanced R&D Focus

- Material Integrity and mitigation
- Monitoring, verification, and accounting
- Lab-based and pilot scale testing and demonstration



Advanced R&D

Harness early-stage transport and storage concepts to technology demonstration

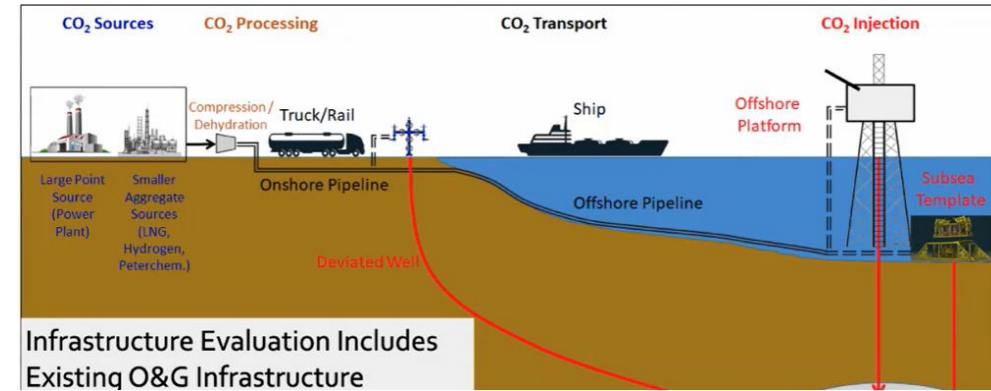
Carbon Transport Research Interests and Direction

What are we interested in?

- Pipeline build out connecting CO₂ sources (Direct Air Capture and Point Source Capture) to CO₂ sinks (secure geologic storage and CO₂ conversion)
- FEED Studies supporting all modes of carbon transport networks
 - Rail
 - Barge
 - Ship
 - Truck
- Repurpose of Existing Infrastructure to support the buildout, both onshore and offshore

How will we accomplish the research, development, and demonstration?

- Coordinating RD&D with **Department of Transportation PHMSA**, **National Labs**, **Department of Interior's Bureau of Safety and Environmental Enforcement (BSEE)**, Industry and Academia.
- Funding Opportunities that create cost-share projects and public-private partnerships
 - BIL 40305: \$100 million, Front End Engineering Design Studies for carbon transport infrastructure
 - BIL 40304: DOE's Loan Programs Office: \$2.1 billion, Carbon Dioxide Infrastructure Finance and Innovation Act (CIFIA)



GOMCARB – Offshore Conference (2022)



GOMCARB – Offshore Conference (2022)

Near-term Lab based RD&D Opportunities

CO2 Impurities/Specifications and Impact to Integrity

- Impurities testing from anthropogenic CO2 sources on corrosion rate, brittleness of steel, two-phase flow conditions of CO2
- Impurities testing from anthropogenic CO2 sources on seals/non-metallic materials performance
- Impurities: H2, H2S, H2O, Particulate Matter, N2, NOx, SOx
- Thermodynamic modeling for CO2 performance across various CO2 source specifications
- Low temperature testing on steel to model depressurization scenarios

CO2 Specific Leak Detection and Emergency Response Protocol

- CO2 dispersion modeling and Potential Impact Radius (PIR) for CO2
- CO2 monitoring and metering across the Carbon Management Value Chain
- R&D potential on odorant additives

Cross-cutting: Repurposing of Existing Infrastructure and Connectivity with Other Modes of Transport

- Testing mechanisms to demonstrate compatibility of transport networks/materials to convert to CO2 use
- Multi-modal modeling and testing supporting other modes: ship, barge, rail, truck, intermodal storage facilities

Bipartisan Infrastructure Law (BIL) Overview

CO2 Transport Infrastructure is an integral component to several BIL Provisions listed in Green.

- **\$12 billion** in new carbon management RD&D: **\$7B** Managed directly by FECM
- **\$9.5B** for hydrogen hubs and RD&D
- Generally, cost share is 80% government/20% applicant for early TRL R&D and 50%/50% for demonstration projects

Point Source Capture and Direct Air Capture

Regional Direct Air Capture Hubs: \$3.5 billion

DAC Technology Prize Competition: \$115 million

CCUS Integrated Demos: \$2.5 billion (OCED)

Carbon Capture Large Pilot: \$1 billion (OCED)

Hydrogen

Hydrogen Hubs: \$8 billion (OCED)

Hydrogen Recycling Program: \$500M

Hydrogen Electrolysis: \$1 billion

Carbon Dioxide Utilization, Transport, and Storage

Carbon Storage Validation and Testing: \$2.5 billion

Carbon Utilization Program: \$310 million

Carbon Transport Systems

FEED Studies for Transport Systems: \$100 million

CIFIA – Loans and Future Growth Grants: \$2.1 billion

Critical Minerals and Materials

Rare Earth Element Demonstration: \$140 million

Rare Earth Mineral Security: \$127 million

<https://www.energy.gov/fecm/solicitations-and-business-opportunities>



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Bipartisan Infrastructure Law Programs | Department of Energy

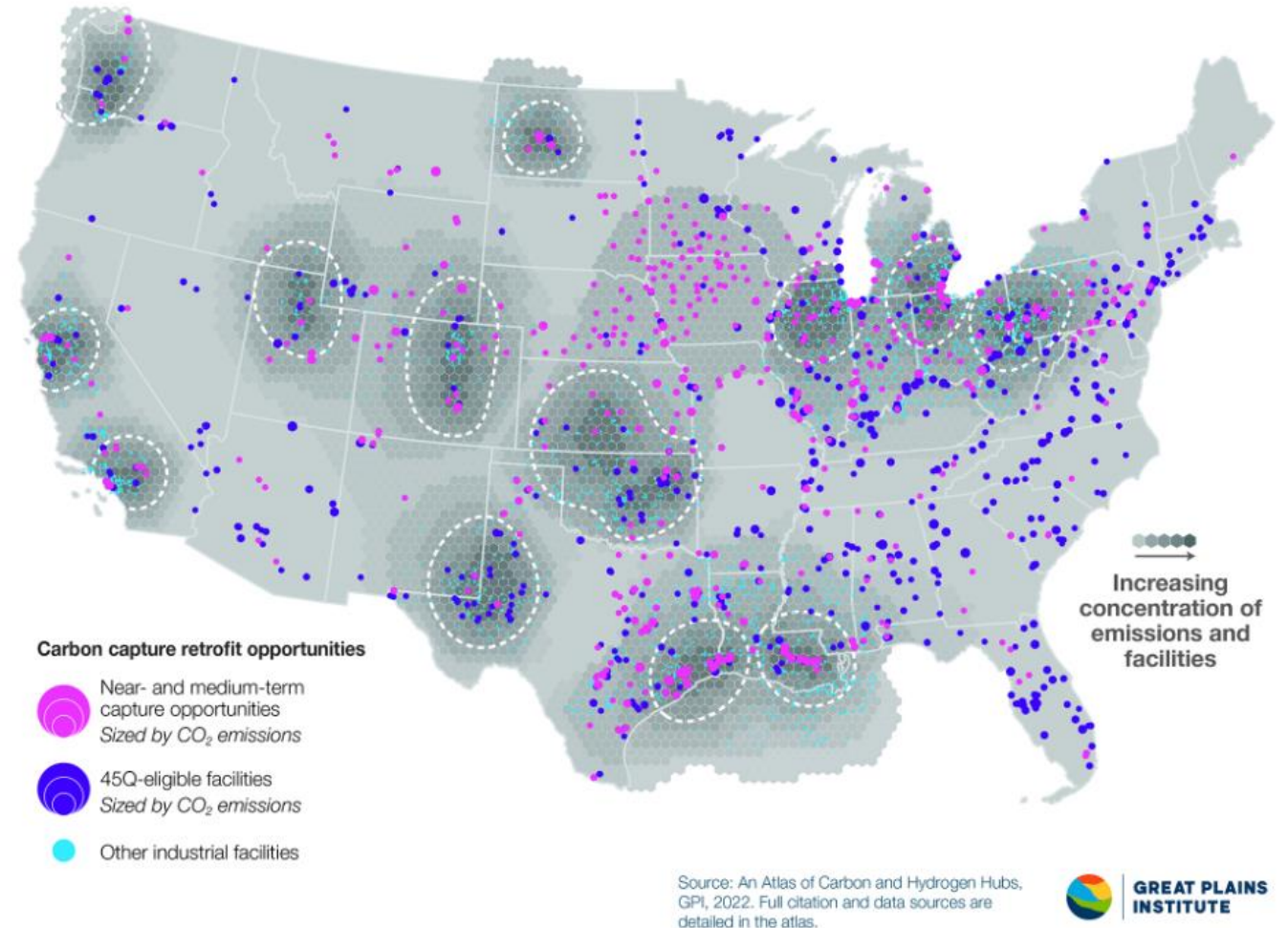
Bipartisan Infrastructure Law: CO2 Transport Front-End Engineering Design (FEED) Studies

Objective:

- \$100 million, \$20M/year for FY22-26
- Supporting front-end engineering design (FEED) studies to enable **new carbon transport buildout or repurposing of existing infrastructure to CO2 use**
- Successful FEED studies can apply for DOE Loan Program Office (LPO)'s **loan guarantees or future growth grants (CIFIA)**
- Carbon transport can include pipeline, barge, ship, rail, and truck transport

Status of funding opportunity:

- **First closing was 11/28/2022**



Bipartisan Infrastructure Law:

Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA)

Loan Authority

- **\$2.1 billion dollars** appropriated for FY22-26
- Provides access to capital for large-capacity, common carrier **carbon transport (pipeline and all transport methods) or repurposing of existing infrastructure to CO2 use and its associated equipment**
- CIFIA Guidance includes eligibility and application requirements: <https://www.energy.gov/lpo/cifia-guidance>

Status of funding opportunity

Portal for No-fee, no-commitment **pre-application consultation is live:**

<https://parc.loanprograms.energy.gov/Content/CIFA/ConsultationRequest.html>

Future Growth Grants

- **Grant program** to support expansion of CO2 transport systems today by **increasing flow rate or capacity** to meet future increases in demand for CO2
- Focused on building for **economies of scale** to form an interconnected carbon management hub/market
- Includes pipeline, barge, ship, rail, and truck transport

Status of funding opportunity:

Request for Information (RFI) released, seeking input until January 17, 2023

<https://www.energy.gov/fecm/request-information-carbon-dioxide-transportation-infrastructure-finance-and-innovation-cifia>

Congressional Report on CO₂ Freight Transportation for Cost-Effective Service, in collaboration with DOT

House Report 117-98 and Senate Report 117-36



CO₂ Freight Transport Workshop

*As industrial deployment of CCUS technology expands, the demand for the transportation of captured carbon oxides is anticipated to increase significantly. In preparation to meet this demand, the Department, in collaboration with the Department of Transportation, is directed to review existing freight transportation infrastructure and the capacity of the various modes of freight transportation to provide cost-effective service. The Department is directed to provide to the Committee not later than 180 days after enactment of this Act a report of the findings of the review. This report should ensure that anticipated short- and long-term freight transportation demand associated with the expanded industrial deployment of CCUS technology is met. Additionally, the report should include analysis of locations where CCUS projects are likely to be located and where carbon sequestration or utilization is likely to occur and the unique aspects of those areas for freight transportation infrastructure. **Finally, in conducting this review, the Department shall consult with stakeholders, including representatives from the various modes of freight transportation.***

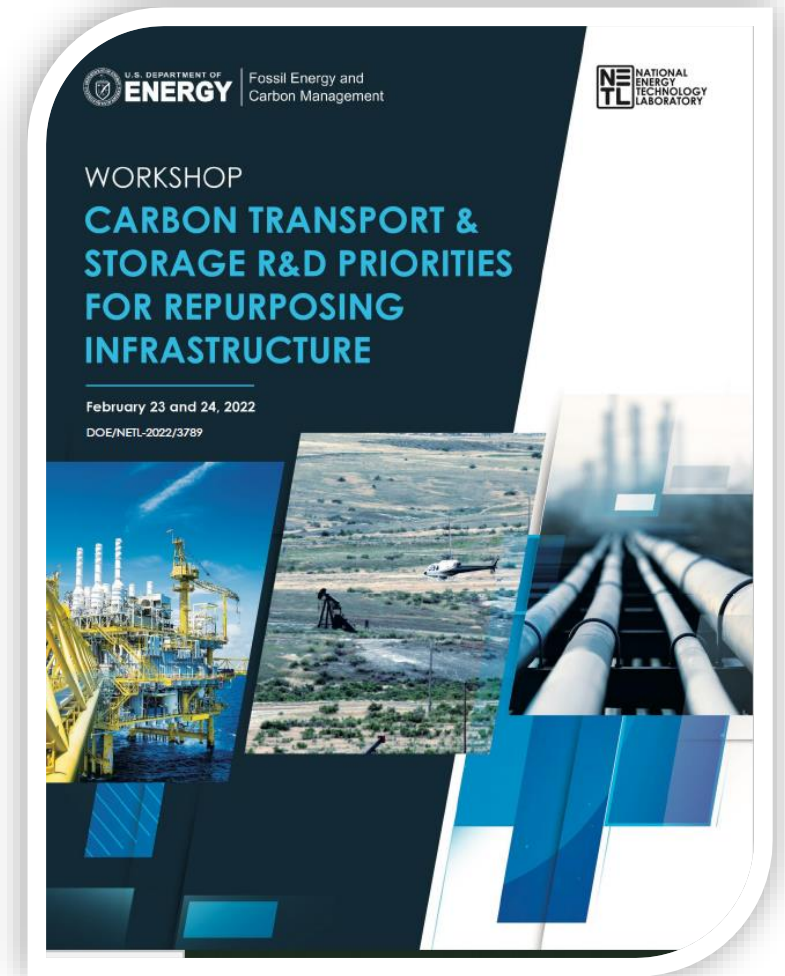


Repurposing Infrastructure R&D Priorities Report – Wells & Pipelines

February 2022 workshop objectives:

- Connecting industry, professional associations, and other government stakeholders active in repurposing pipeline and wells infrastructure for carbon transport and storage research, development, demonstration, and deployment (RDD&D) projects.
- Improving understanding about the challenges and opportunities in meeting future carbon transport and storage goals.
- Exploring technical advancements, operational considerations, RDD&D gaps, and regulatory considerations for conversion of use of pipeline and well infrastructure for carbon transport.

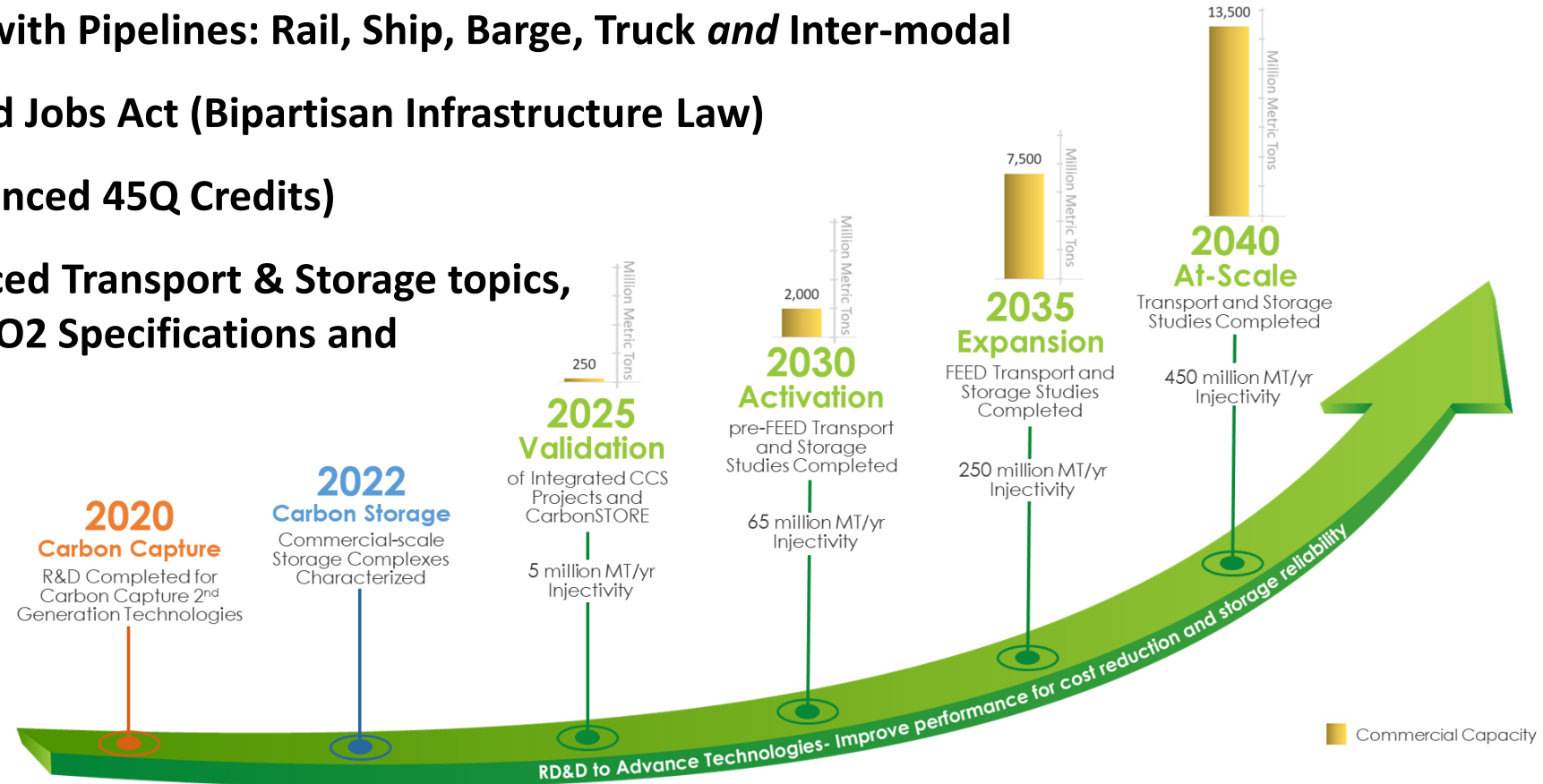
Outcomes: Report collated action items and observations across Technical R&D, Policy, and Regulatory considerations from a consortium of industry, academic, and government stakeholders



DOE Carbon Transport and Storage: A Look Forward

Accelerating CCUS Infrastructure to Meet Decarbonization Goals

- **All-of-Government and Industry approach:** Interagency collaborations with federal agencies including DOT, DOI (BSEE/BOEM/USGS), EPA, USDA, Coast Guard, Army Corp of Engineers.
- **CO2 Transport incorporated with Pipelines: Rail, Ship, Barge, Truck *and* Inter-modal**
- **Infrastructure Investment and Jobs Act (Bipartisan Infrastructure Law)**
- **Inflation Reduction Act (Enhanced 45Q Credits)**
- **Continued RD&D into Advanced Transport & Storage topics, Decarbonization Modeling, CO2 Specifications and Materials Performance**





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Questions?

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Legend:

- Light Rare Earth Elements
- Heavy Rare Earth Elements
- Critical Rare Earth Elements
- Critical Minerals

H																	He	
Li	Be											B	C	N	O	F	Ne	
Mg												Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

* Ga, K, Rb, Cs, Fr, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr are not included with rare earth elements.



BIL: Regional Clean Hydrogen Hubs

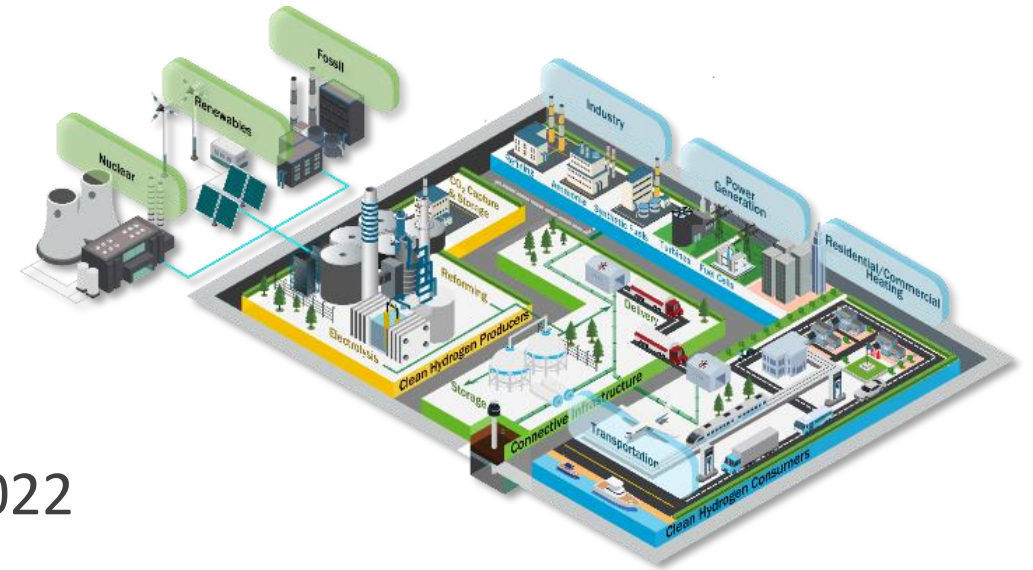
<https://www.energy.gov/oced/regional-clean-hydrogen-hubs>

Build 6-10 regional clean H2Hubs across the country to create networks of hydrogen producers, consumers, and local connective infrastructure to accelerate use of hydrogen

- Feedstock diversity
- End use diversity
- Geographic diversity
- Employment and training

Current Status

- Issued funding announcement in September 2022
 - Planning 6-10 awards ranging from \$400M-\$1.2B
 - Concept papers are due by Nov 7, 2022
 - Full applications are due by April 7, 2023



Inflation Reduction Act (IRA): Incentives/Thresholds

CCUS: 45Q Modifications

	Old	New
Commence Construction	January 1, 2026	January 1, 2033
DAC Facility	100,000 metric tons/year*	1,000 metric tons/year
Electric Generator	500,000 metric tons/year*	18,750 metric tons/year
All other facilities	100,000 metric tons/year*	12,500 metric tons/year
Saline Storage Credit	\$50/metric ton	\$85/metric ton (industry and power); \$180/metric ton (DAC)
EOR and Conversion Credit	\$35/metric ton	\$60/metric ton (industry and power); \$130/metric ton (DAC)

* Non-EOR Conversion facilities were previously 25,000 metric tons/year regardless of facility/source.

Notes: New Modifications allows up to 5 years for direct pay (up to 12 years certain entities)

[Text - H.R.5376 - 117th Congress \(2021-2022\): Inflation Reduction Act of 2022](#) | [Congress.gov](#) | [Library of Congress](#)

DOE's Carbon Matchmaker

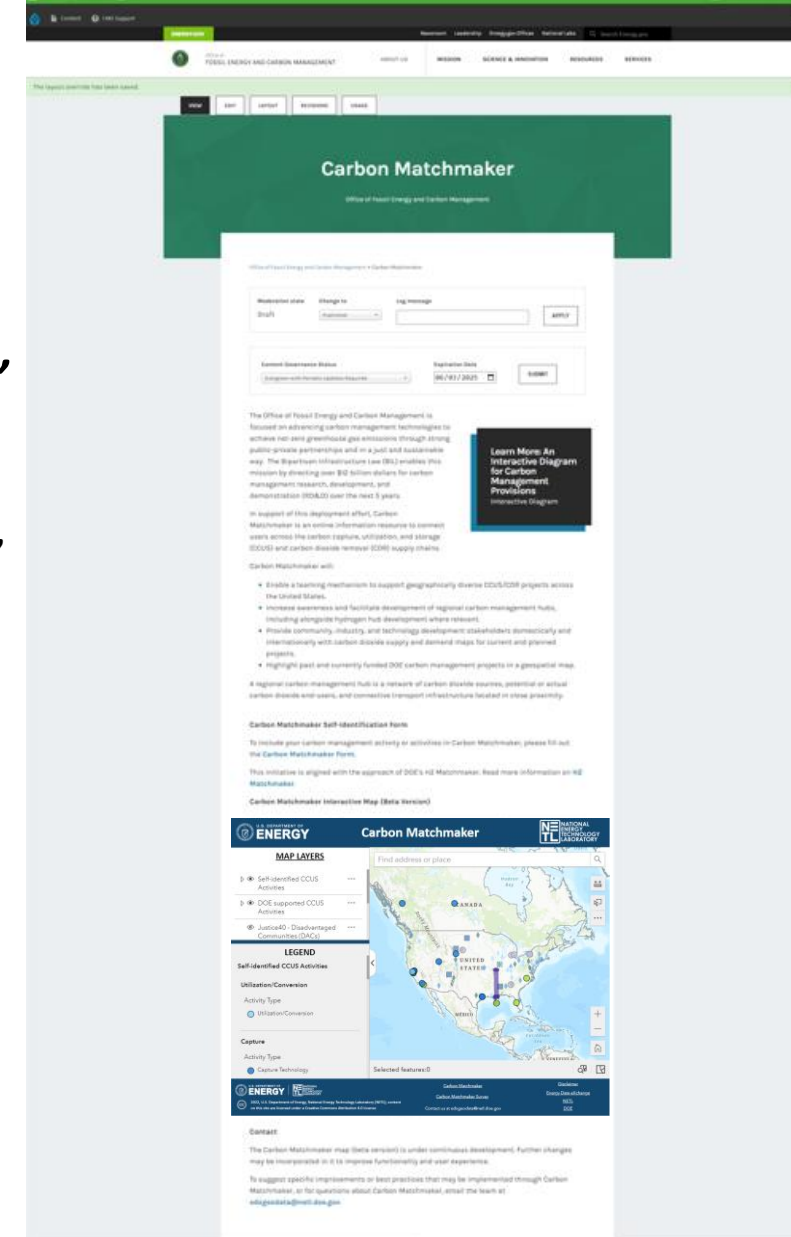
A partnering and teaming tool for DOE carbon management funding opportunities, mirroring DOE's H2 Matchmaker.

Carbon Matchmaker is an online information resource to connect users across the carbon capture, utilization, and storage (CCUS) and carbon dioxide removal (CDR) supply chains.

Carbon Matchmaker will:

- Enable a teaming mechanism to support geographically diverse CCUS/CDR projects across the United States.
- Increase awareness and facilitate development of regional carbon management hubs, including alongside hydrogen hub development where relevant.
- Provide community, industry, and technology development stakeholders domestically and internationally with carbon dioxide supply and demand maps for current and planned projects.
- Highlight past and currently funded DOE carbon management projects in a geospatial map.

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



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energy.gov/fecm

