



# Industrial Efficiency & Decarbonization Office (IEDO)

Energy- and Emissions-Intensive Industries  
Isabelle Sgro Rojas (Energetics) on behalf of  
Paul Majsztrik, PhD-Program Manager



# Industrial Efficiency & Decarbonization Office (IEDO)

U.S. DEPARTMENT OF  
**ENERGY**

Office of ENERGY EFFICIENCY  
& RENEWABLE ENERGY

**IEDO** leads the development and accelerates the adoption of sustainable technologies that increase efficiency and eliminate industrial GHG emissions.

**50**  
STAFF

Federal staff, contractors,  
and fellows in Golden, CO  
and DOE Headquarters

**\$266.5**  
Million FY23 Budget



**Energy- and  
Emissions-  
Intensive  
Industries**

FY23 = \$131M



**Cross-sector  
Technologies**

FY23 = \$90.5M

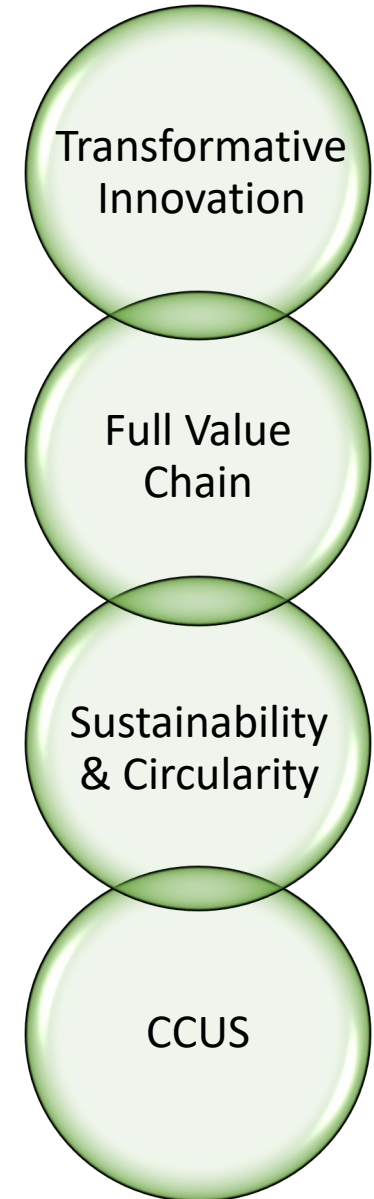


**Technical  
Assistance  
and Workforce  
Development**

FY23 = \$45M

# IEDO Strategy

- 1) **Technology Solutions:** Drive development of next generation transformative tech through collaborative and targeted RD&D (lab-scale to pilot demos).
- 2) **Full Value Chain:** Look outside the production plant at materials, design, and products.
- 3) **Sustainability & Circularity:** Reduce not just carbon emissions, but energy use, waste production, and natural resources depletion. Incorporate recycling and material reuse (LCAs & TEAs).
- 1) **CCUS:** Collaborate with FECM on carbon capture process integration and use of CO2 as a feedstock in materials, chemicals, fuels.



# Energy- and Emissions-Intensive Industries Program

EIIP's Mission: Identify & accelerate the readiness of emerging, industry-specific technologies to decarbonize the most energy- and emissions-intensive industrial subsectors.



## CEMENT & CONCRETE

367 TBtu  
66 MMT CO<sub>2</sub>e



## CHEMICALS

(including production of  
low-carbon fuels)  
4,842 Tbtu  
332 MMT CO<sub>2</sub>e



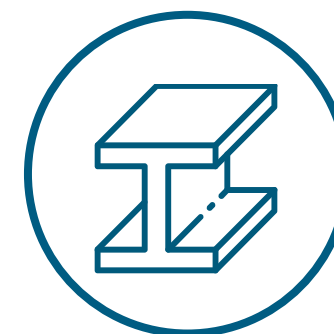
## FOOD & BEVERAGE

1,935 TBtu  
96 MMT CO<sub>2</sub>e



## FOREST PRODUCTS

2,883 TBtu  
80 MMT CO<sub>2</sub>e



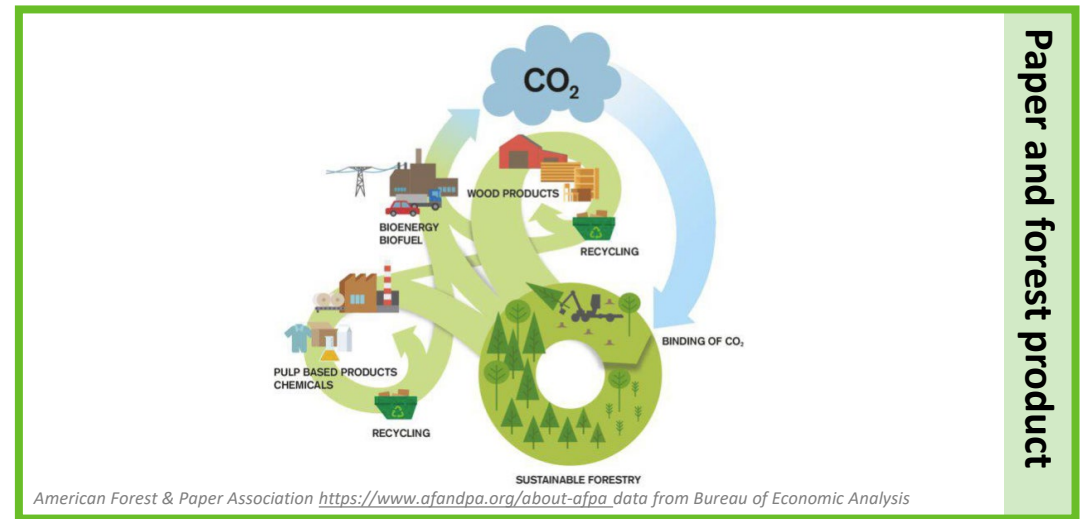
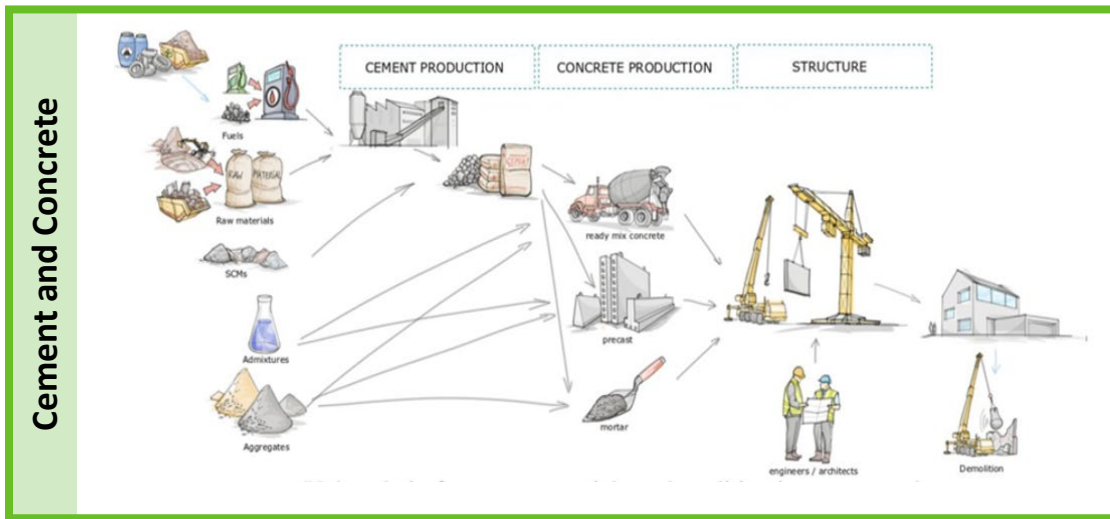
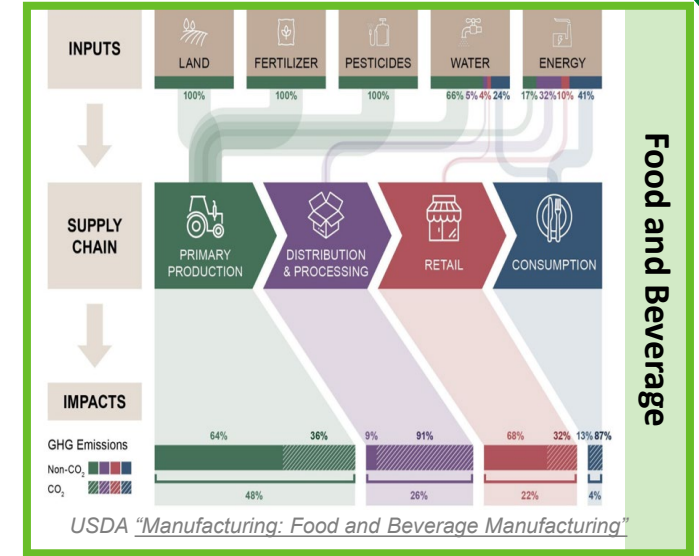
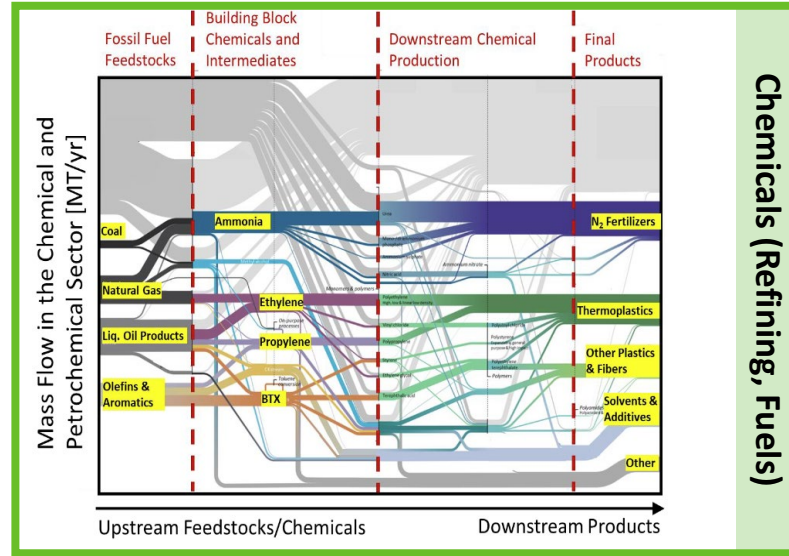
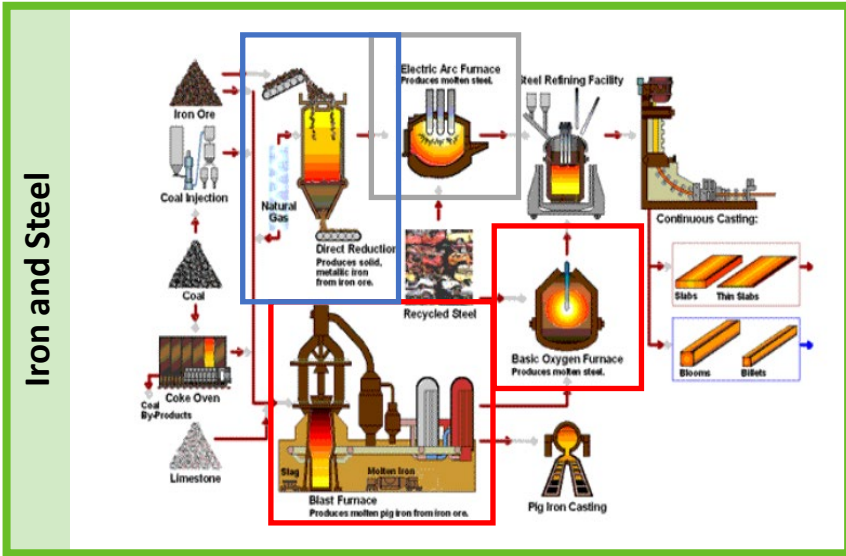
## IRON AND STEEL

1,469 TBtu  
100 MMT CO<sub>2</sub>e

DOE [Manufacturing Energy and Carbon Footprint](#), based on EIA Manufacturing Energy Consumption Survey (MECS) data for 2018



# Sector Value Chains: Raw Materials, Process, Final Products



# Iron and Steel - Decarbonization Strategies

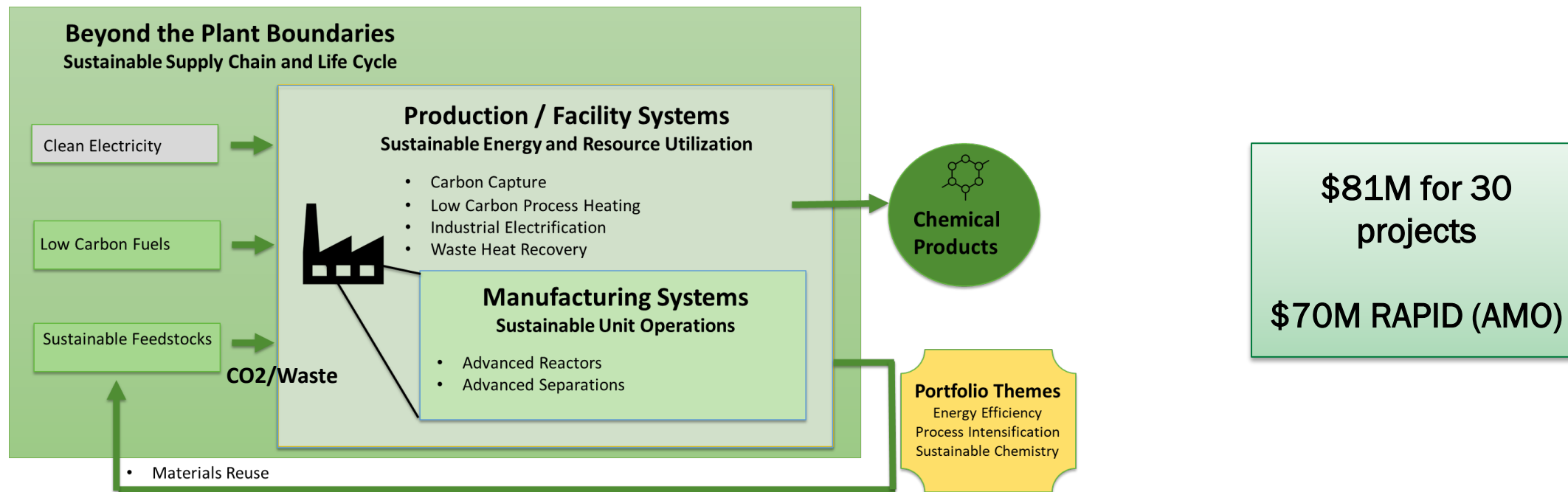
\$58M for 15 projects

Priorities	Current Portfolio including FY22 awards
Alternative Ironmaking	\$6M across 3 projects
Smart Manufacturing	\$12.3M across 2 projects (Blast furnace and Arc furnace)
Bio-sourced carbon steelmaking	\$6M across 2 projects
Process Heating Decarbonization	\$24.7M across 3 projects for both hydrogen burners and electric heating
Contaminants, tramp elements	\$3.5M across 2 projects

## Key FY 2024 Planned Investments

- **Alternative Ironmaking Processes** with rapid scalability and deployment potential, electrical & novel-chemical ore reduction.
- **Ore improvement and beneficiation:** DR based processes require high grade ore that are becoming increasingly scarce<sup>1</sup>. Improving the quality of ore supply is critical to support the H<sub>2</sub>-DRI to EAF production route
- **Address scrap contaminants** from a supply (e.g. improved scrap sorting), process (novel processes that allow for removal of Cu, Sn, Ni etc.), and product (increased tolerance to residual elements) perspective.
- **Low-C steelmaking** technologies and practices that allow for production of high value, technically challenging flat products with minimal carbon intensity

# Chemicals and Refining - Decarbonization strategies



Priorities	Current Portfolio	*projects counted in multiple categories
Energy/Material Efficiency	<ul style="list-style-type: none"> <li>• \$49M across 21 projects including advanced reactors</li> <li>• \$16M across 5 applied R&amp;D projects on catalytic systems, membrane separations</li> </ul>	
Sustainable Feedstocks (CO <sub>2</sub> )	<ul style="list-style-type: none"> <li>• \$42.5M across 18 applied R&amp;D including CO<sub>2</sub> from industrial processes and CC/DAC, biomass/biogas</li> </ul>	
Low Carbon Energy Sources	<ul style="list-style-type: none"> <li>• \$34M across 16 applied R&amp;D projects including electrochemical manufacturing, non-contact heating, low carbon process heating</li> <li>• \$17M across 2 pilots including rotary olefine cracker and electromagnetic heating</li> </ul>	

# Cement & Concrete – Decarbonization Strategies

## FY22 IEDO Industrial Decarbonization FOA (\$135M)

Priorities	Current Portfolio
CCU – Alternative SCMs	<ul style="list-style-type: none"> <li>•\$10.5M across 3 R&amp;D projects using CO<sub>2</sub> captured from cement kiln flue gas</li> <li>•\$ 3.3M specifically for biochar utilization</li> </ul>
Alternative Binder	<ul style="list-style-type: none"> <li>•\$ 2.7M across 1 R&amp;D project focused on low-carbon hybrid cement</li> <li>•\$ 0.6M across 1 lab call project focused on new binder and concrete scale-up</li> </ul>

**Portfolio focus: Innovation across multiple areas to achieve deep Carbon reduction**

## FY23 IEDO Multi-topic FOA (\$156)

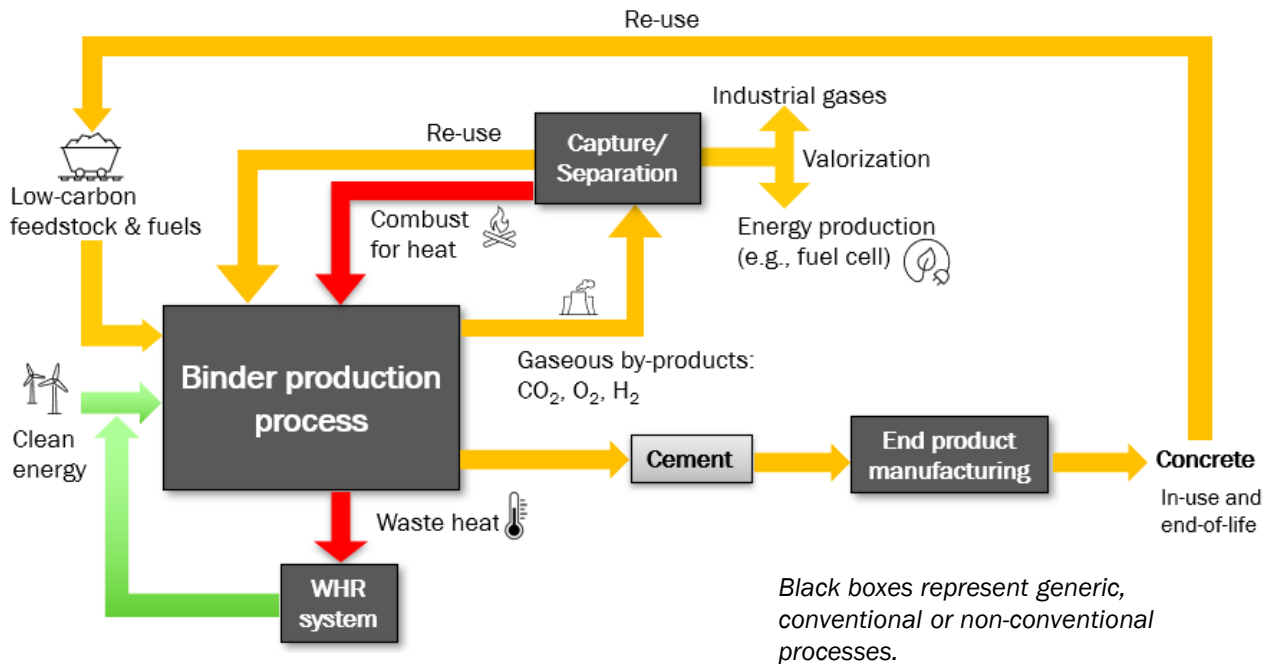
- Currently Reviewing Proposals

## FY23 IEDO-AMMTO-BTO TCF Lab Call (\$2.4M)

- Topic 1: Greener Buildings and Building Materials with Reduced Embodied Carbon

## FY24 priorities

1. Alt. binders & SCMs; accelerate development & adoption
2. Process innovation (deep & economical emissions reductions)
3. Cement and concrete circularity, **CO2 mineralization**
4. Integrated decarbonization strategies for low-emissions cement production (**includes integrated Carbon Capture**)





# Other sectors:

## Food & Beverage

### Key FY 2024 Planned Investments

1. **Alternative proteins production** (cultivated, plant-based, others) to significantly reduce the GHG emissions associated with the livestock farming (Scope 3) and processing (Scope 1 and 2)
2. **Innovations in deep waste energy recovery (>50%) and its onsite reuse** for food and beverage industrial operations (integrated approach)
3. **Reduction in energy consumption (>75%) and carbon footprint (>85%)** during the post-harvesting activities (seasonal, regional, poor efficiency, high spoilage, high innovation potential)

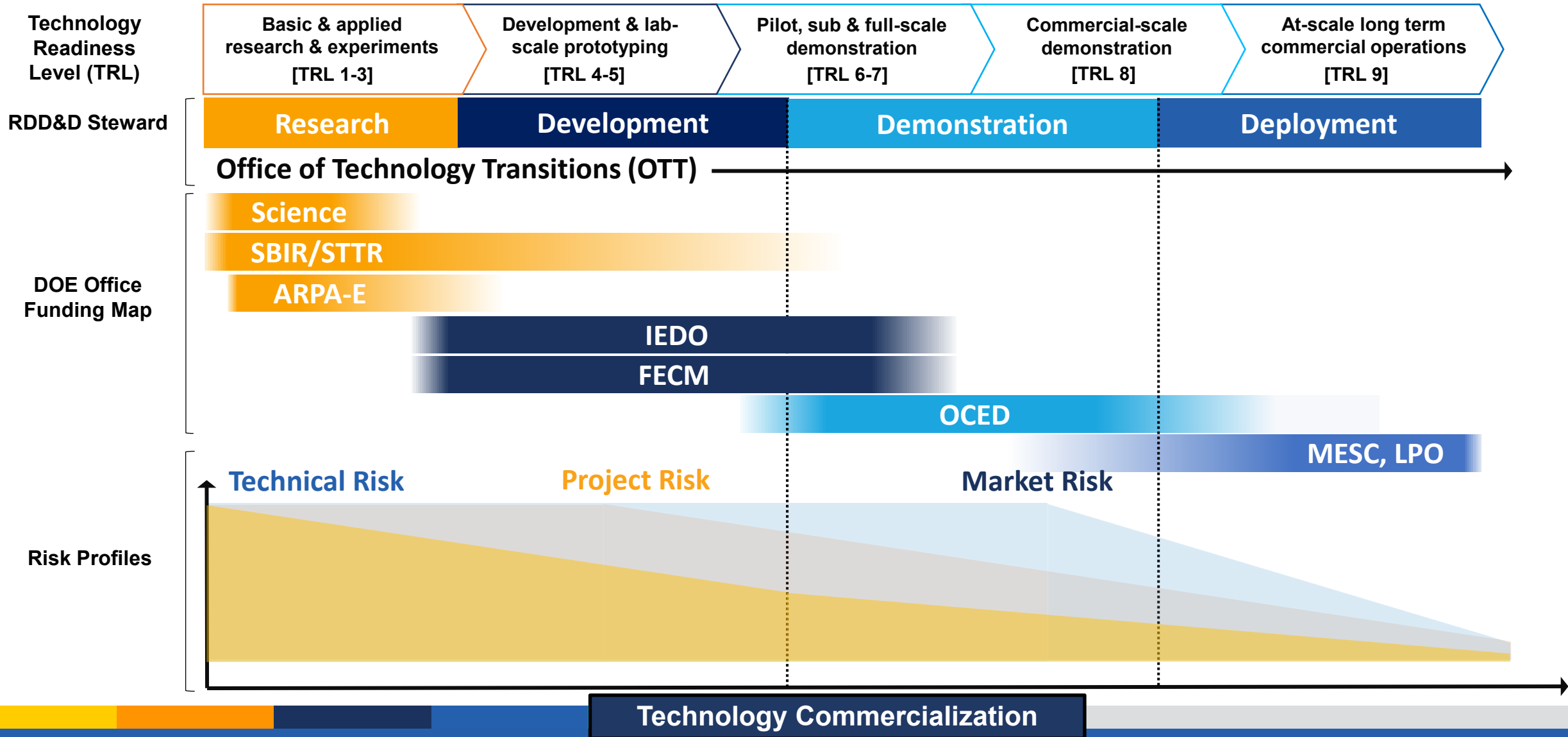
## Forest Products Industries

### Key FY 2024 Planned Investments

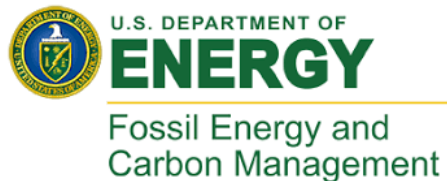
- **Novel pulping chemistries** including biological pulping, catalytic-assisted pulping, deep eutectic and other solvents
- **Alternatives in chemical recovery** including advanced separations, alternative chemical recovery processes, lime kiln emissions reduction (including carbon capture)
- **Transformative dewatering/drying processes and energy recovery techniques** including integrated heat pumping, waste heat recovery and electrification

**Actively Building Sector-Specific Portfolios**  
Beyond Existing Cross-Sector Projects

# Role Across Research, Development, Demonstration & Deployment (RDD&D) Continuum



# Interoffice Collaboration



# Thank You!

## Paul Majsztrik, PhD

Program Manager, IEDO  
Energy- and Emissions-Intensive Industries  
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## Isabelle Sgro Rojas

Program Support (Energetics)  
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Solutions for Today | Options for Tomorrow

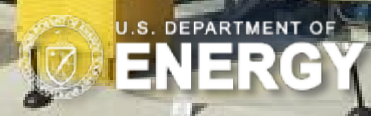
# Point Source Carbon Capture For Industrial Decarbonization



NETL Carbon Management Research  
Project Review Meeting  
August 31, 2023



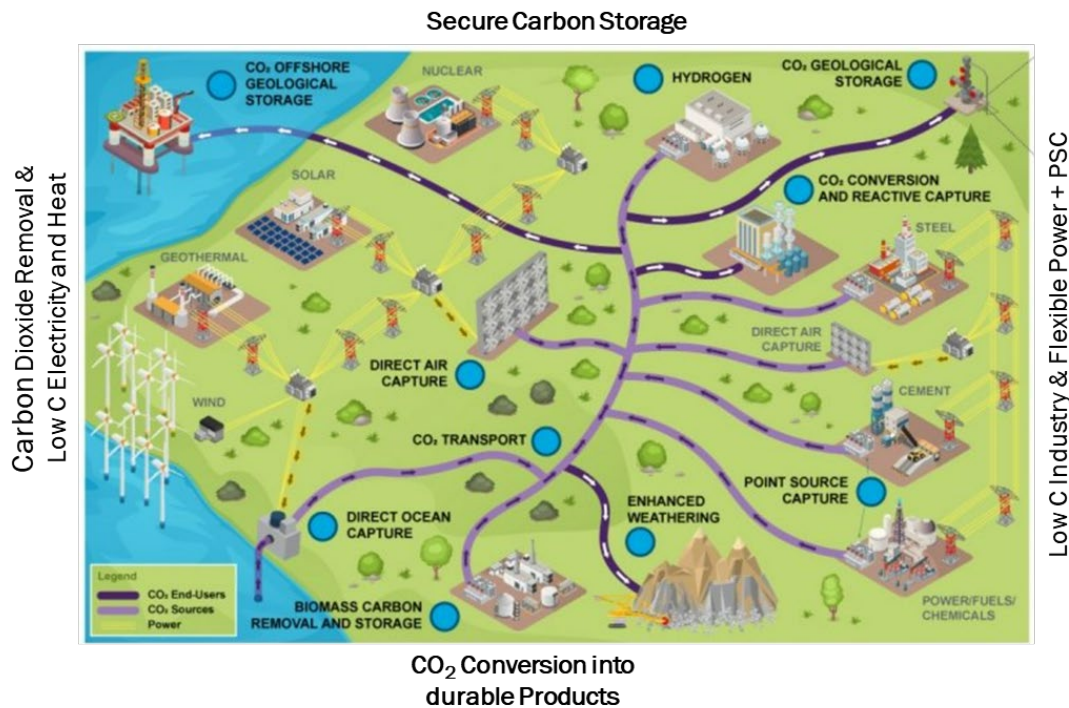
**Ron Munson**  
Point Source Carbon Capture  
Technology Manager  
National Energy Technology Laboratory





# 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.

# PSC Industrial Portfolio




## Bench



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

No storage

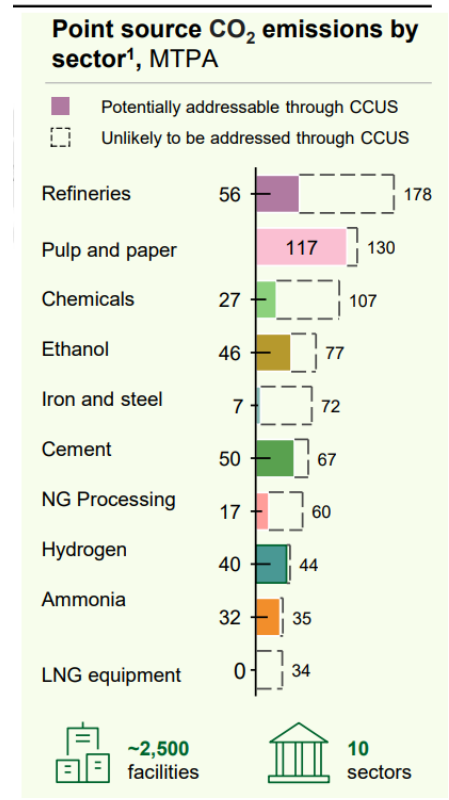
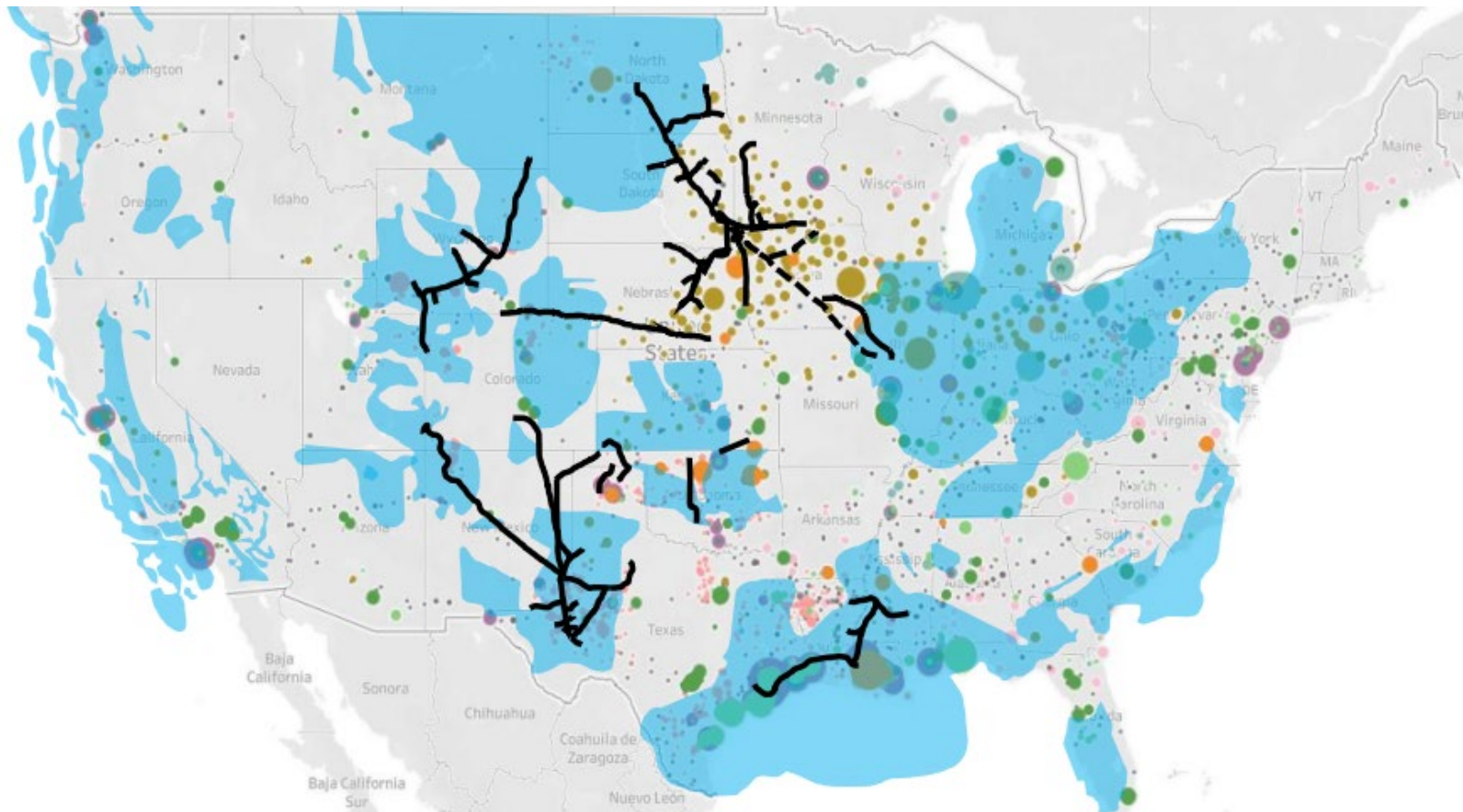
## CCS Demo



Carbon transport & storage

<b>IEDO</b>	✓	✓		
<b>FECM</b>	✓	✓	✓ TCM (FCC)	
<b>OCED</b>				✓ Min 75 kta      BIL Funded      ✓ Min 300 kta

# Carbon management is one solution to address industrial emissions



○ 2 MTPA     
 ○ 8 MTPA     
  Saline Aquifers     
  CO<sub>2</sub> proposed pipeline<sup>2</sup>     
  CO<sub>2</sub> existing pipeline

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



# 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

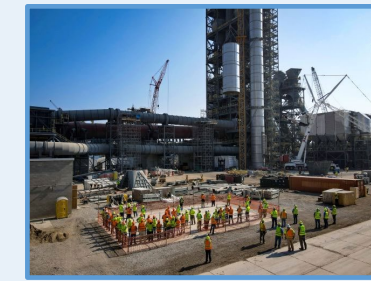
Air Liquide' Cryocap FG



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

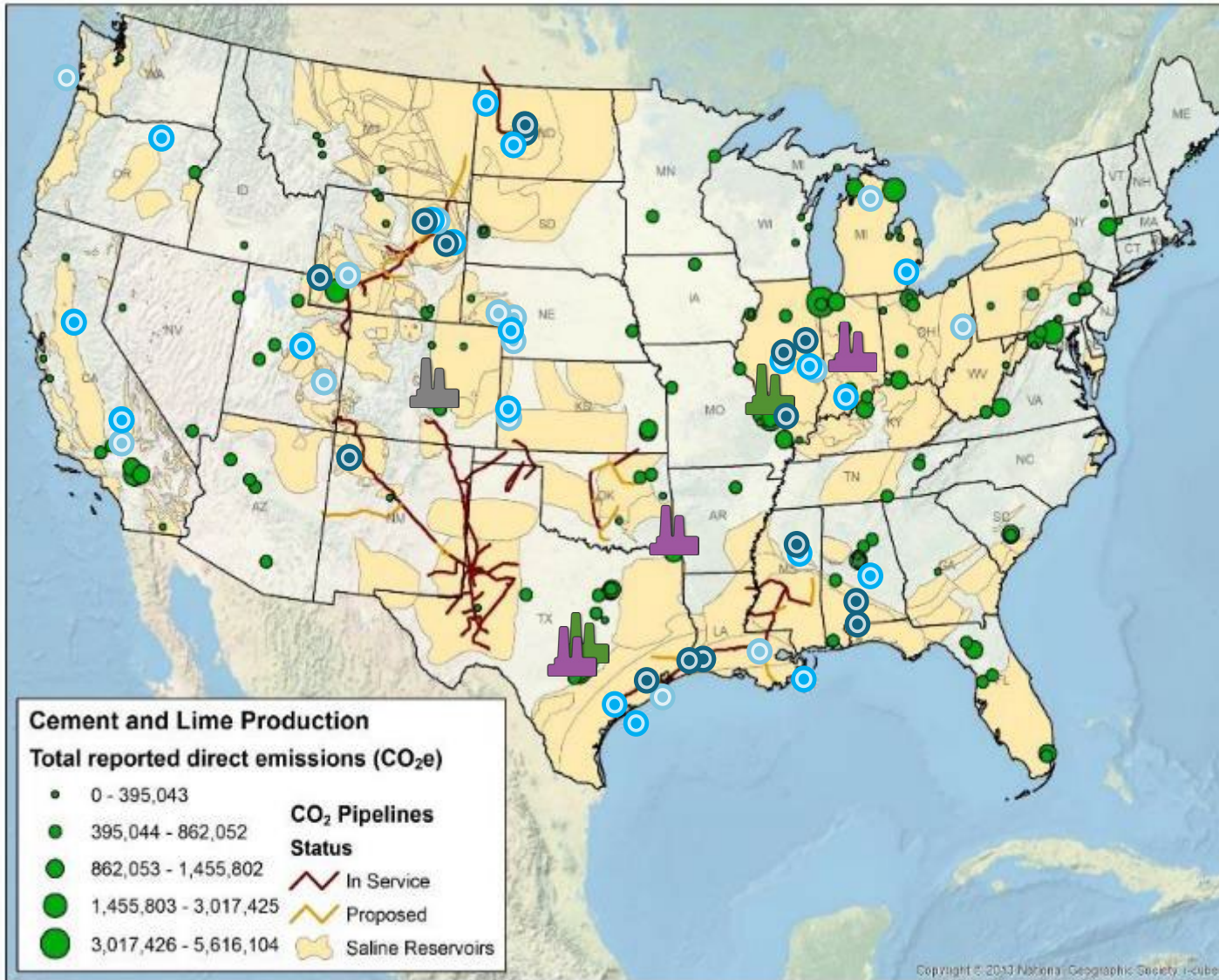


Ash Grove Foreman  
Foreman, AR

Air Liquide' Cryocap FG



# Cement FEED Studies



## Carbon Capture FEEDs/Pre-FEEDs

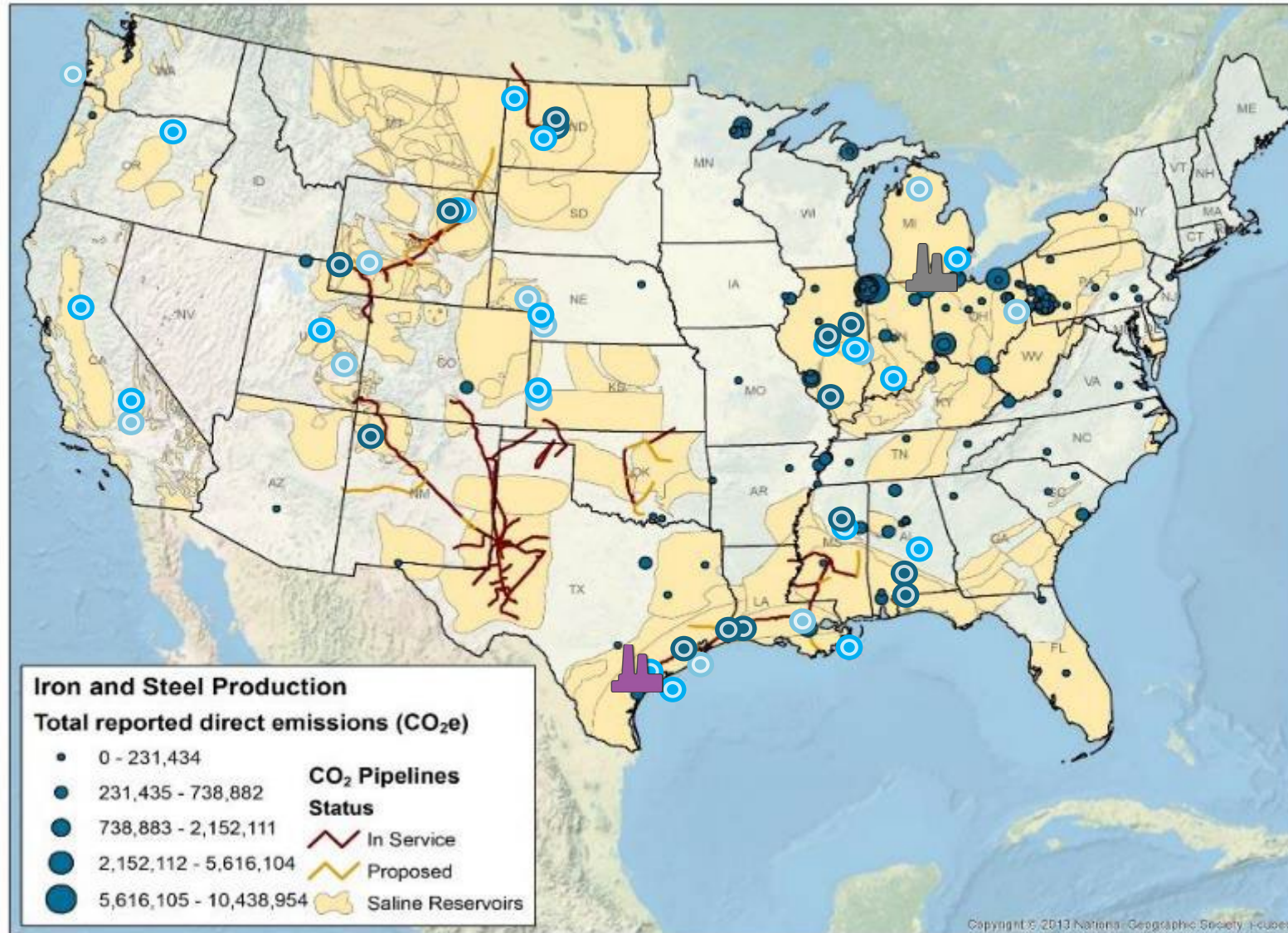
- Active
- Completed
- Not Awarded Yet

## CarbonSAFE

- Phase I: Pre-Feasibility
- Phase 2: Feasibility
- Phase 3: Site Characterization and CO<sub>2</sub> Capture Assessment



# Iron and Steel FEED Studies



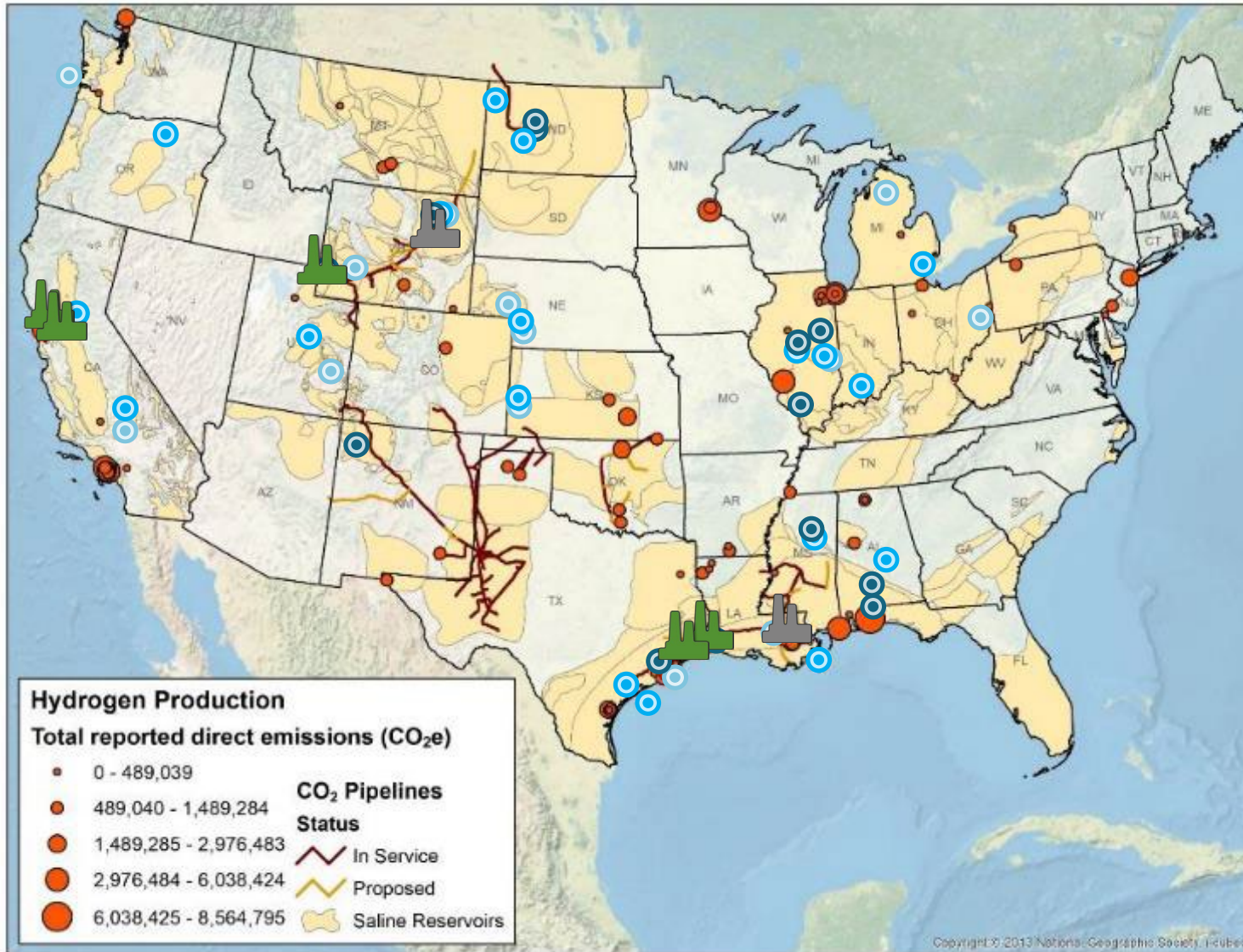
## Carbon Capture FEEDs/Pre-FEEDs

- Active
- Completed
- Not Awarded Yet

## CarbonSAFE

- Phase 1: Pre-Feasibility
- Phase 2: Feasibility
- Phase 3: Site Characterization and CO<sub>2</sub> Capture Assessment

# Hydrogen Production FEED Studies



## Carbon Capture FEEDs/Pre-FEEDs

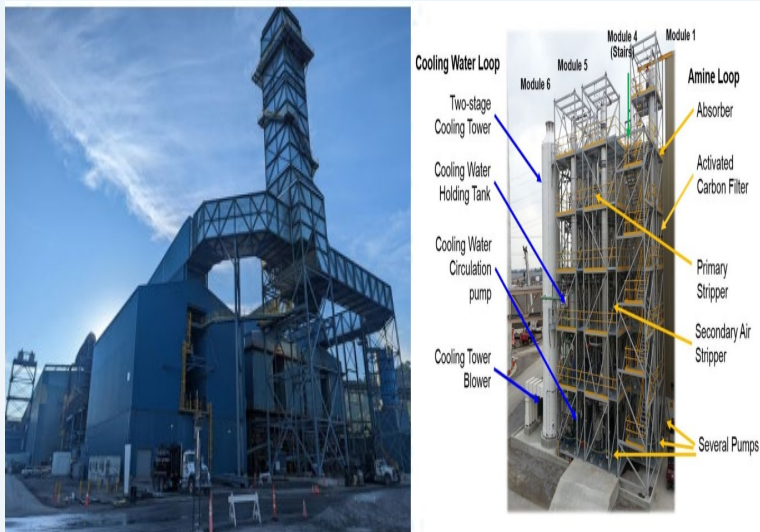
- Active
- Completed
- Not Awarded Yet

## CarbonSAFE

- Phase I: Pre-Feasibility
- Phase 2: Feasibility
- Phase 3: Site Characterization and CO<sub>2</sub> Capture Assessment



## Uky/Nucor Pilot Carbon Capture 3 tonne/day



- Nucor Steel Gallatin Plant – Electric Arc Furnace
- 1.5% CO<sub>2</sub> flue gas
- High O<sub>2</sub> 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<sub>x</sub>, SO<sub>x</sub>, and other pollutants
- CO<sub>2</sub> compression occurs as a liquid, reducing cost and energy demand

# 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.

## FOA 2614 Round 3: Summary

**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% CO<sub>2</sub> 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 CO<sub>2</sub>/day.

## FOA 2614 Round 4: NOI



**NATIONAL ENERGY TECHNOLOGY LABORATORY**  
Albany, OR • Morgantown, WV • Pittsburgh, PA



Notice of Intent No.: DE-FOA-0003159

**DISCLAIMER:** The "Notice of Intent to Issue" is for informational purposes only; the Department of Energy is not seeking comments on the information in this notice and applications are not being accepted at this time. Any information contained in this notice is subject to change.

**This is a Notice of Intent to Issue**  
**Funding Opportunity Announcement No. DE-FOA-0002614**  
**Title: Carbon Management (Round 4)**

The Department of Energy (DOE) National Energy Technology Laboratory (NETL) intends to issue Funding Opportunity Announcement (FOA) No.: DE-FOA-0002614 on behalf of the Office of Fossil Energy and Carbon Management (FECM) late in the 2023 calendar year.

### **AOI-3. Point Source Carbon Capture Technology**

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 CO<sub>2</sub> with over 95% efficiency that is suitable for secure geologic carbon storage, including in situ mineralization or CO<sub>2</sub> conversion into long-lasting products (e.g., synthetic aggregates, concrete, durable carbon products).

### *AOI-3D. Decarbonization of Industrial Processes Using Chemical Looping Approaches*

The objective of AOI-3D is to perform conceptual design studies followed by a laboratory validation of cost-effective processes for employing chemical looping approaches that lead to reductions in CO<sub>2</sub> emissions associated with industrial production processes. Industrial sectors of interest include: (i) chemical production (e.g., petrochemicals), (ii) mineral production (e.g., cement, lime), (iii) pulp and paper production, (iv) iron and steel production, (v) glass production, and (vi) oil refining (e.g., catalytic cracker, hydrocracking). A phased approach is currently planned for AOI-3D with a competitive down-select between Phase 1 and Phase 2. Only entities that receive a Phase 1 award will be permitted to submit a Phase 2 renewal application for consideration under the competitive down-selection process.

[FedConnect: Opportunity Summary](#)



# 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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Business and Industry News	07
Publications	08

## 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 (FOAs) to bolster investments in the carbon management industry and to significantly reduce carbon dioxide (CO<sub>2</sub>) 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 CO<sub>2</sub>, along with associated CO<sub>2</sub> 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 CO<sub>2</sub>. **Carbon Dioxide Transport Engineering and Design** provides up to \$100 million to design regional CO<sub>2</sub> pipeline networks to safely transport captured CO<sub>2</sub> from key sources to centralized locations.

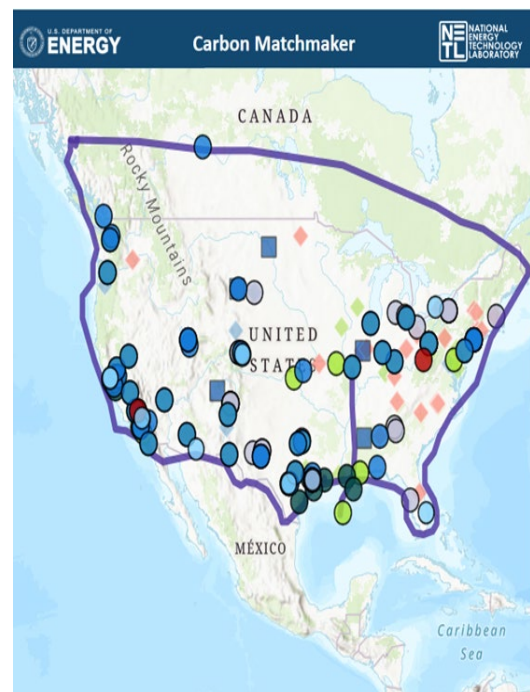
*Carbon Capture Newsletter*



## CARBON CAPTURE PROGRAM R&D COMPENDIUM of CARBON CAPTURE TECHNOLOGY

U.S. DEPARTMENT OF ENERGY  
NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

*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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**NATIONAL  
ENERGY  
TECHNOLOGY  
LABORATORY**





**OCED**  
Office of Clean Energy Demonstrations

# THE OFFICE OF CLEAN ENERGY DEMONSTRATIONS



## Industrial Demonstrations Program

G. Jeremy Leong, Ph.D.  
Program Manager

# OCED Mission

Deliver clean energy technology **demonstration projects at scale** in partnership with the **private sector to accelerate deployment, market adoption**, and the **equitable transition** to a decarbonized energy system.”

## OCED Mandate



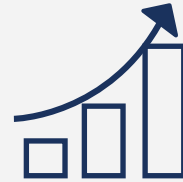
### CENTER OF EXCELLENCE

Serve as primary DOE office to deliver full scale clean energy demonstration projects and project management oversight excellence



### CLEAN ENERGY & EQUITABLE

Help enable 100% clean electricity by 2035 and net zero emissions by 2050 through an equitable energy transition



### FOLLOW ON INVESTMENT

Unlock and scale trillion-dollar clean energy follow on investment from the private sector and other sources of capital



### DE-RISK TECHNOLOGY

Maintain risk-based, balanced, and defensible portfolio of investments



### ENGAGEMENT & OUTREACH

Leverage private sector and broader energy ecosystem to inform OCED and DOE technology commercialization efforts





A photograph of an industrial manufacturing environment. In the center, a large vertical cylindrical component is being processed, with bright orange molten metal visible inside. A shower of bright orange sparks is falling from the top of the component. The background is filled with industrial machinery, pipes, and structural beams, illuminated by blue and white overhead lights.

## Industrial Demonstrations

Received funding from the Bipartisan Infrastructure Law and Inflation Reduction Act to demonstrate transformational technologies to decarbonize energy-intensive industries.

- Solidify a first-mover advantage for U.S. industry in low- and net-zero carbon manufacturing
- Substantiate the market for clean products through high-impact, replicable solutions
- Build broadly shared prosperity for American workers and communities

### ***Current Status***

- Issued \$6B funding announcement in March 2023
- Concept papers were due in April 2023
- Full applications were due August 11, 2023

# Industrial Demonstrations Program Purpose



IDP is part of the Industrial Emissions Reduction Technology Development Program which was enacted to:



Increase industry/manufacturing competitiveness in US



Increase US industrial technology export competitiveness



Achieve emissions reduction in nonpower industrial sectors








# Program Overview

The Industrial Demonstrations Program offers up to **\$6 billion** for transformational, advanced industrial facilities that can achieve deep decarbonization in energy intensive industrial subsectors.

## Project Types

-  **Near-Net-Zero Facility Builds**
-  **Facility-level Installations and Overhaul Retrofits**
-  **System Upgrades and Retrofits for Critical Unit Operations or Single Process Lines**

## Program Priorities

- Deep decarbonization**, by demonstrating significantly less carbon-intensive industrial production processes
- Timeliness**, through rapid technology demonstrations that can address emissions in the near-term, meet funding horizons, and be replicated by fast followers
- Market viability**, with projects spurring follow-on investments and partnerships between buyers and sellers of materials
- Community benefits**, tailored through labor and community engagement; diversity, equity, inclusion, and accessibility; environmental justice; and opportunities for communities



6/1  
Encourage / Discourage Notifications

8/11 @ 5 p.m. ET  
Applications Due

Winter 2023/2024  
Selections Announced



# Project Types

All values anticipated

## Topic Area 1



~\$100M – \$250M federal share\*



~2 – 5 projects



Near-Net-Zero Facility Build Projects

*World-leading, first- or early-of-a-kind, full facility builds resulting in significant emissions reductions up to net-zero operations.*



8-12 years anticipated.  
No statutory funding deadline.

## Topic Area 2

~\$75M – \$500M federal share\*

~10 – 30 projects

Facility-level Large Installations and Overhaul Retrofit Demonstrations

*Large-scale overhauls for existing facilities, common technologies across multiple facilities, or new builds with accelerated planning, development, permitting, and financing strategies.*

3 – 7 years anticipated.

**Projects should aim to reach Phase 3 (construction) by Sept. 30, 2026.**

## Topic Area 3

~\$35M – \$75M federal share\*

~10 – 30 projects

System Upgrades and Retrofits for Critical Unit Operations or Single Process Lines Within Existing Facilities

*Upgrades, retrofits, and operational improvements that target decarbonization within a unit operation or process line at an existing facility or facilities.*



# Concept Paper Overview

		Total Projects	Total DOE Funding Requested	Total Private Sector Cost Share
<b>Concept Paper Requests</b>	Chemicals and Refining	153	\$25.1B	\$46.9B
	Iron, Steel, and Steel Mill Products	40	\$11B	\$22.7B
	Cement and Concrete	53	\$5.8B	\$8.3B
	Pulp and Paper	26	\$3.4B	\$3.8B
	Aluminum	17	\$2.6B	\$2.8B
	Glass	17	\$2.3B	\$2.4B
	Cross-cutting	26	\$3.5B	\$3.7B
	Other Energy-Intensive Industrial Processes	79	\$8.1B	\$9.1B
<b>Totals</b>	Total Requests	411	>\$60B	~\$100B
	Total Encouraged	130		
	Total Target Awards	22-65	\$6B	





# Collaboration Strategies for Industrial Decarbonization

## OCED Scope



Regional Clean Hydrogen Hubs (\$8 billion)



Long-Duration Energy Storage Demonstrations (\$505 million)



Advanced Reactor Demonstrations (\$2.5 billion)



Energy Improvements in Rural or Remote Areas (\$1 billion)



Carbon Management (\$7 billion)



Clean Energy Demonstrations on Mine Land (\$500 million)



Industrial Demonstrations (\$6.3 billion)



New Demonstration Projects (\$50 million – and hopefully more!)



U.S. DEPARTMENT OF ENERGY  
Energy Efficiency & Renewable Energy



U.S. DEPARTMENT OF ENERGY  
Fossil Energy and Carbon Management

Significant interagency potential to maximize funding and support for related sectors

**H2:** BIL 40314 - \$8B  
45V PTC

**CCUS:** BIL 41004 - \$2.5B  
45Q TC

**Small & Medium Manufacturers:**  
BIL 40521 - \$400M  
BIL 40209 - \$750M

**Multiple:** 48C ITC - \$10B  
LPO Title 17  
EPA Low-emodied Emissions Construction Materials  
EPA Climate Pollution Reduction Grants  
Buy Clean



**OCED**  
Office of Clean Energy Demonstrations

# Overview: Pathways to Commercialization Liftoff



Pathways to Commercial Liftoff represents a new DOE-wide approach to deep **engagement between the public and private sectors**.

Goal is **catalyzing commercialization and deployment of technologies** critical to our nation's net-zero goals.

Pathways to Commercial Liftoff started in 2022 to:

- **collaborate, coordinate, and align with the private sector** on what it will take to commercialize technologies
- provide a **common fact base** on key challenges (e.g., cost curve)
- establish a **live tool and forum** to update the fact base and pathways



# Exact decarbonization levers and capital for net-zero varies by sector

**PRELIMINARY – VALUES SUBJECT TO CHANGE**

NOT EXHAUSTIVE

ILLUSTRATIVE  
Industrial Sector Lens

U.S. stage of commercialization

Deployable Demo R&D / Pilot

Limited relevance for sector decarbonization

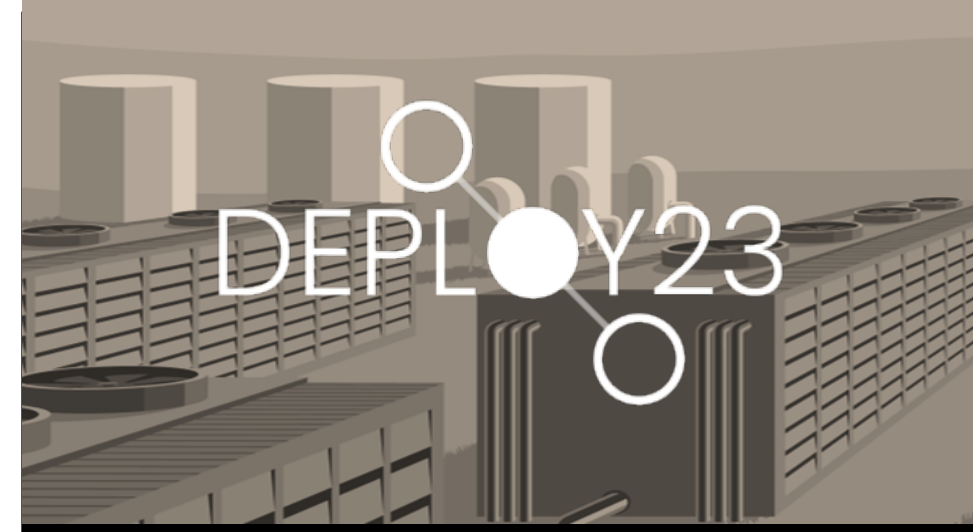
Decarbonization Levers Lens	Chemicals	Refining	Iron & Steel	Food & Beverage	Cement	Pulp & Paper	Aluminum	Glass
	<b>CCS (with H2 production)</b>	Various	FCC <sup>2</sup> , process heat, SMR <sup>3</sup>	BF-BOF <sup>4</sup> , NG-DRI/HBI <sup>5</sup>		Rotary kiln	Black liquor boiler	Smelting
<b>Industrial electrification</b>	Low-high temp heat alternatives	Low-high temp heat alternatives	EAF <sup>6</sup> transition	Low temp heat alternatives	Pre-calc, kiln	Low-mid temp heat alternatives	Low temp, high temp, process	High temp melting
<b>Energy efficiency</b>	Various	Various	Various	Various	Various	Various	Various	Various
<b>Electrolytic Hydrogen</b>	Clean ammonia production	Hydrocracking, hydrotreating <sup>9</sup>	H2-HBI	Boiler	Rotary kiln	Boilers, burners	Calciner	Melting
<b>Raw material substitutions</b>	Recycling	Bio-based feedstock	NG-DRI/HBI <sup>5</sup>		Clinker substitution	Recycling	Recycling	Recycling, silica alternatives
<b>Alt. fuel (non-H2)</b>				Boilers, various equipment	Rotary kiln	Boilers, burners		Melting
<b>Alt. production methods</b>	Bio-based plastics <sup>1</sup>		Ironmaking processes	Various <sup>8</sup>	Electrochemical <sup>7</sup>		Carbochlorination, inert anode	
<b>Potential capex needed</b>	\$400-600B	\$200-300B	\$25-40B	\$5-15B	\$50-110B	\$10-15B	\$5-15B	\$5-15B

1. Ethanol dehydration | 2. Fluid Catalytic Cracker | 3. Steam Methane Reformer | 4. Blast Furnace – Basic Oxygen Furnace | 5. Natural Gas – Direct Reduced Iron / Hot Briquetted Iron | 6. Electric Arc Furnace | 7. Geopolymers | 8. E.g., absorption chillers, ejector refrigeration, deep waste energy and water recovery, alternative protein manufacturing | 9. Refers to H2 use in traditional processes



# Upcoming Event: DEPLOY23

- Invitees are senior leaders in industry and across sectors
- Focus on deployment challenges of clean technology investments across key sectors
- Main workshop focus areas:
  - Industrial Decarbonization
    - CCS
    - Industrial Heat
    - Chemicals and Refining
    - Procurement and Buy-Side Mobilization
  - Grid Modernization
  - Virtual Power Plants
  - Carbon Dioxide Removal
- In-person participation is by invitation only; select content will be made available on DOE channels after Deploy23



CO-HOSTED BY



September 26 – 27 in Washington, DC (<https://www.deploy23.org/Home>)



# Questions?

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