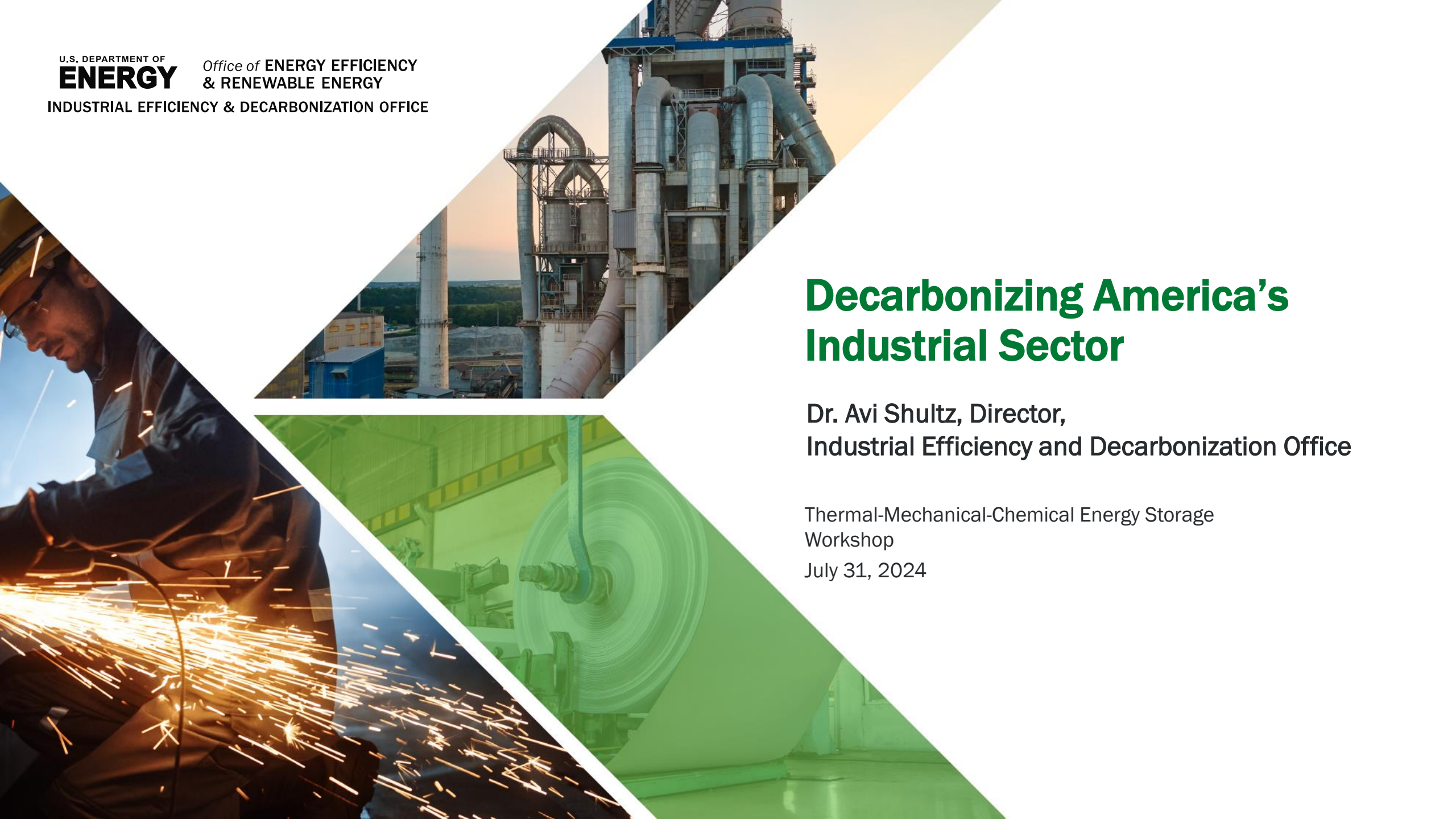




Decarbonizing America's Industrial Sector

Dr. Avi Shultz, Director,
Industrial Efficiency and Decarbonization Office

Thermal-Mechanical-Chemical Energy Storage
Workshop
July 31, 2024

Building a Net-zero, Clean Energy Future

The U.S. industrial sector (manufacturing, agriculture, mining, and construction) accounts for:

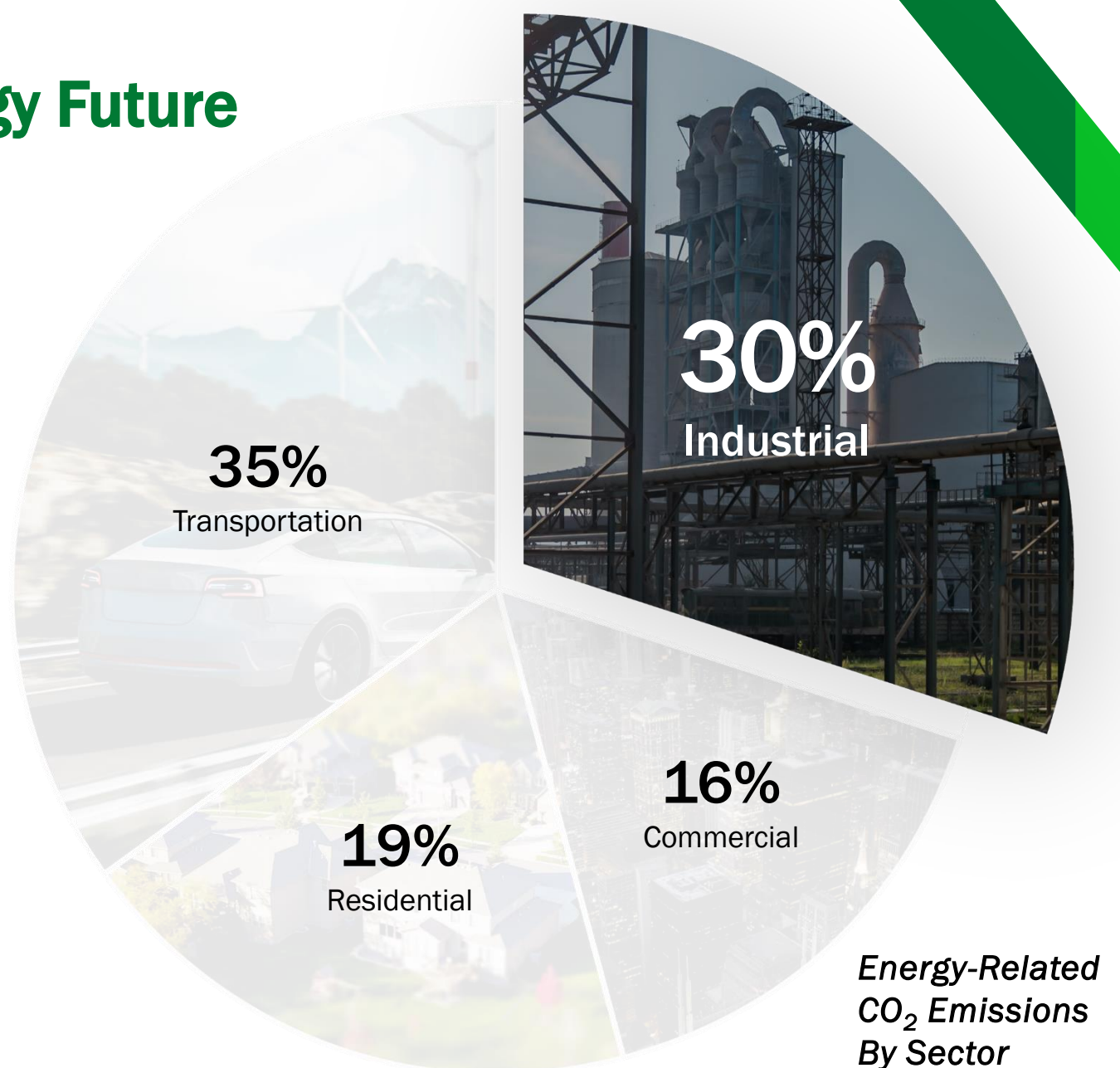
33% of the nation's primary energy use

30% of CO₂ emissions

Anticipated industrial sector energy demand growth of 30% by 2050 may result in a:

17% CO₂ emissions increase*

*EIA, Annual Energy Outlook 2021 with Projections to 2050.



Decarbonizing Industry is an Opportunity for America's Economy

U.S. manufacturing
subsector...



CONTRIBUTES

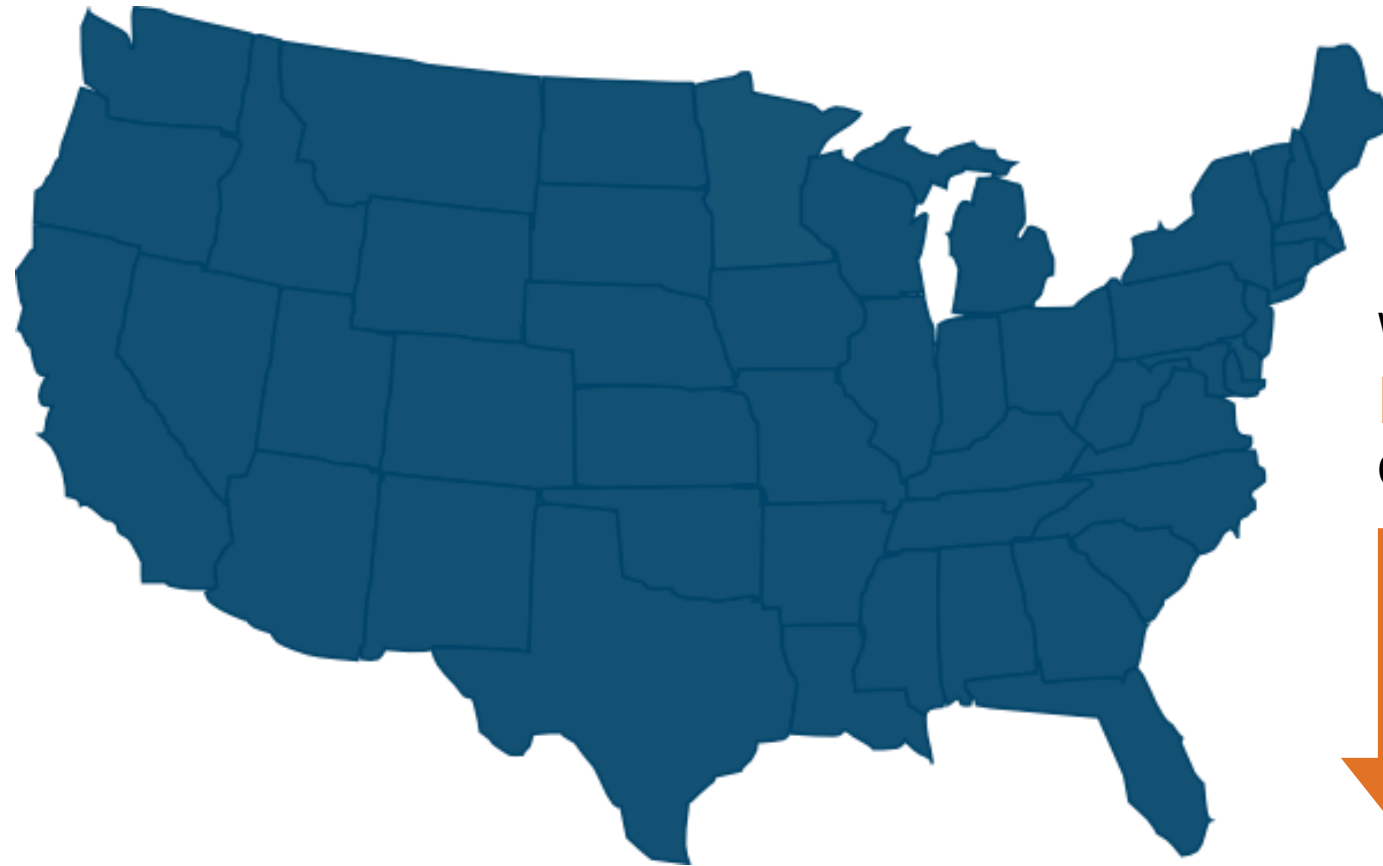
\$2.35 trillion to
the U.S. Economy

GENERATES

11% of U.S. GDP

CREATES

11.4 million jobs



While working to
DECREASE
CO₂ emissions



Systemic barriers to industrial decarbonization

Investment scale → In the range of

\$700 Billion –

1.1 Trillion

just for 8 industrial sector of focus in the IRA :



Chemicals



Refining



Iron &
Steel



Food &
Beverage



Cement



Pulp &
Paper



Aluminum



Glass

Estimated that

60% 

by 2030 will come from technologies that are not net-positive decarbonization levers with existing IRA tax credits or require further R&D to address

Targeted investment for research, development, and pilot-scale demonstrations is a need and opportunity for U.S. manufacturing

Source: DOE Pathways to Commercial Liftoff; Industrial Decarbonization https://liftoff.energy.gov/wp-content/uploads/2023/10/LIFTOFF_DOE_Industrial-Decarbonization_v8.pdf

DOE Industrial Decarbonization Roadmap

Industrial Decarbonization Pillars



Energy
Efficiency



Industrial
Electrification



Low-Carbon Fuels,
Feedstocks, and Energy
Sources (LCFFES)



Carbon Capture,
Utilization, and
Storage (CCUS)

Decarbonization pillars: inter-related, cross-cutting strategies to pursue in parallel



Iron & Steel



Chemicals



Food & Beverage



Petroleum Refining

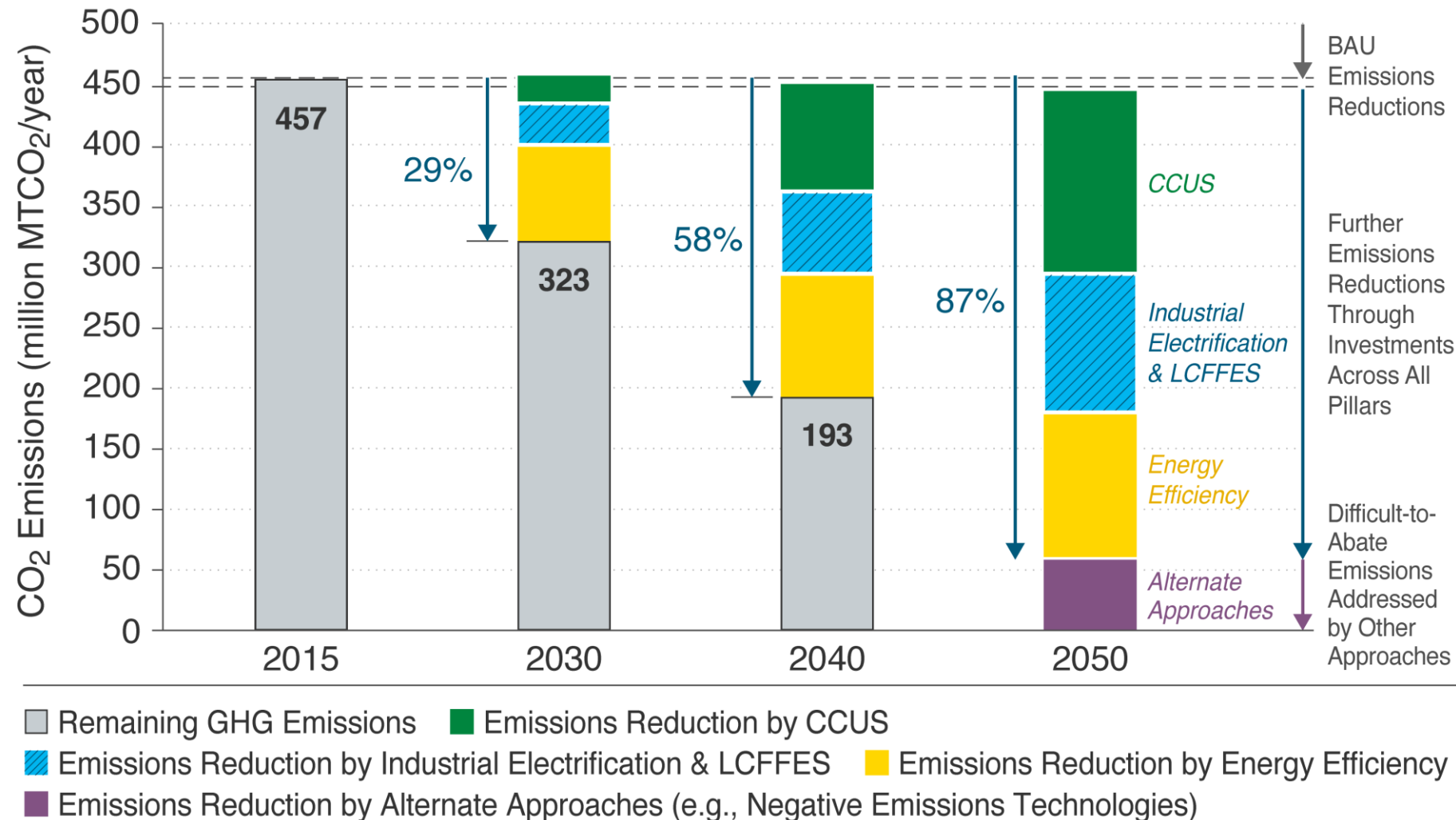


Cement



www.energy.gov/eere/doe-industrial-decarbonization-roadmap

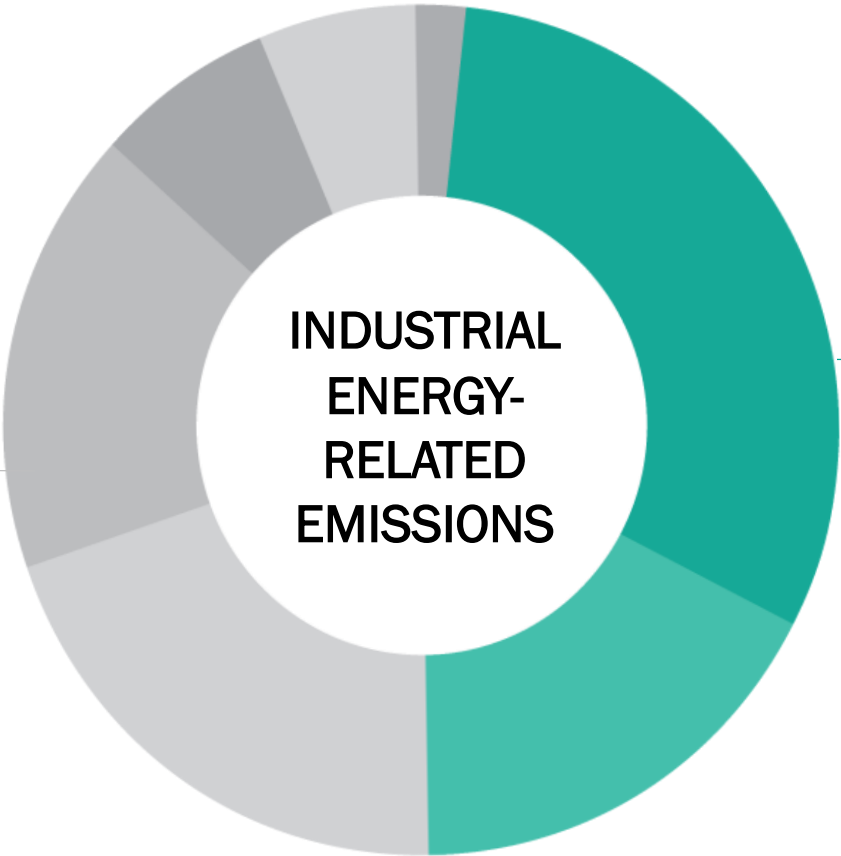
Path to Net-Zero Emissions by 2050



Expanded Approach for All of Industry

The 6 heavy emitting subsectors evaluated in the Roadmap:

- Iron/steel
- Pulp/paper
- Chemicals
- Food/beverage
- Refining
- Cement/concrete



THE REST OF INDUSTRY

- Other Manufacturing
- Construction
- Mining, Oil, & Gas
- Water & Wastewater Treatment
- Agriculture & Forestry
- Data Centers

The rest of industry represents nearly half of the industrial sector’s energy-related emissions.

The Path Forward

Building on the foundation of Roadmap, DOE is conducting a new holistic vision study. *Pathways for U.S. Industrial Transformations: Unlocking American Innovation* will:

- Identify **cost-effective and industry-specific strategic pathways** to achieve a thriving U.S. industrial sector with net-zero greenhouse gas (GHG) emissions by 2050
- Address the **technological, economic, societal, and environmental & health impacts** associated with the scale and pace of an industrial transformation.
- Present **strategies, targeted pathways, metrics, and targets**, for overcoming challenges and barriers.

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Reimagining the Industrial Sector of the future

Decrease emissions

There is no single pathway to decarbonization that will work for any single industrial subsector. **We must pursue multiple pathways in parallel for each industrial subsector.**

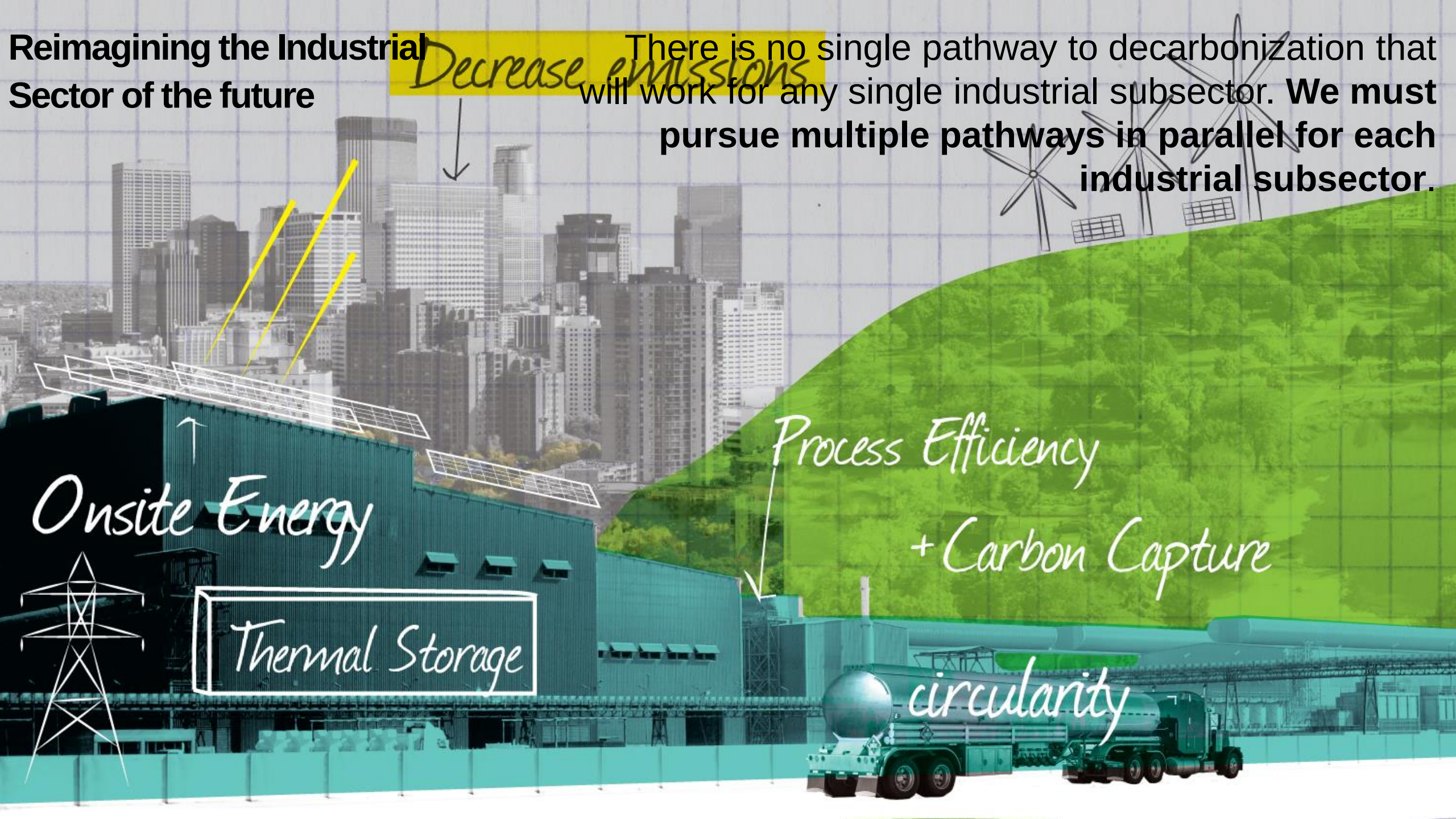
Onsite Energy

Thermal Storage

Process Efficiency

+ Carbon Capture

circularity



Primary Challenges and Barriers to Industrial Decarbonization



Thermal Systems Emissions. Represent about half of all energy-related industrial emissions with over 90% due to fossil fuel combustion.



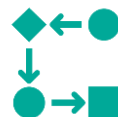
Process Emissions. Emissions from chemical or physical transformations are intrinsic to many current industrial processes – i.e., cement production.



Constraints within Industrial Entities. Industrial entities' operation and structure can limit zero-emissions technologies adoption and material and energy efficiency improvements in existing processes.



Decarbonization Infrastructure. All decarbonization pathways will require the expansion of decarbonization infrastructure.



Inefficient Information Flows. Data privacy concerns and lack of information sharing can impact the scale and speed of industrial decarbonization efforts.



Underrepresented Social Criteria. Protecting the workforce and associated communities that interact with industry is a priority during the clean energy transition.

Framework for Industrial Decarbonization Pathways



Net-Zero Emissions Pathway: A set of specific actions needed to achieve progress in and across the decarbonization pillars, while remaining informed and supplemented by RD&D to advance viable solutions that will need to be adopted at scale in the marketplace.

- Major production routes
- Emissions reduction
- Factors impacting how facilities will evaluate and choose technologies
- Timing for technology deployments
- Major uncertainties, risks, and barriers
- Prioritization of retrofits and greenfield facilities

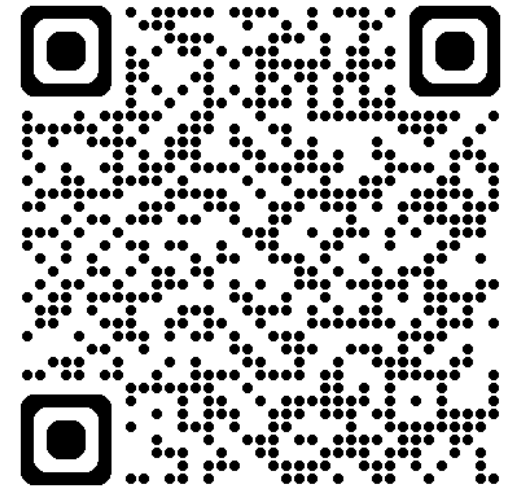
Transforming Industry: Strategies for Decarbonization RFI

The RFI will inform the *Pathways for U.S. Industrial Transformations: Unlocking American Innovation* study:

IEDO seeks input on the following categories:

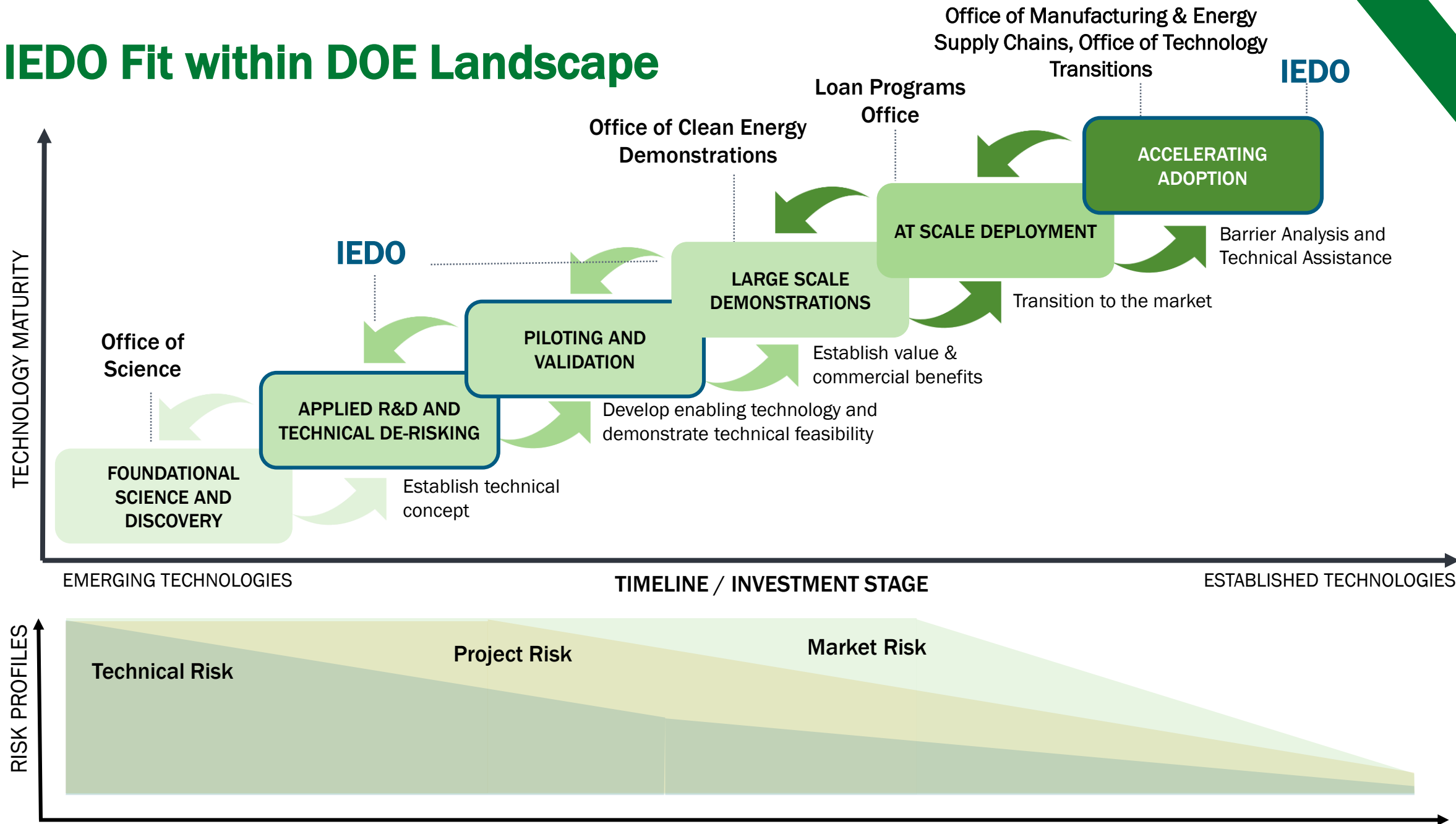
- Industrial Decarbonization Barriers, Challenges, and Cross-Cutting Strategies
- Framework for Industrial Decarbonization Pathways
- Impacts and Evaluation Criteria for Industrial Decarbonization Pathways; and
- Net-zero Decarbonization Pathways for Specific Industrial Subsectors

www.energy.gov/eere/iedo/industrial-decarbonization-pathways-modeling

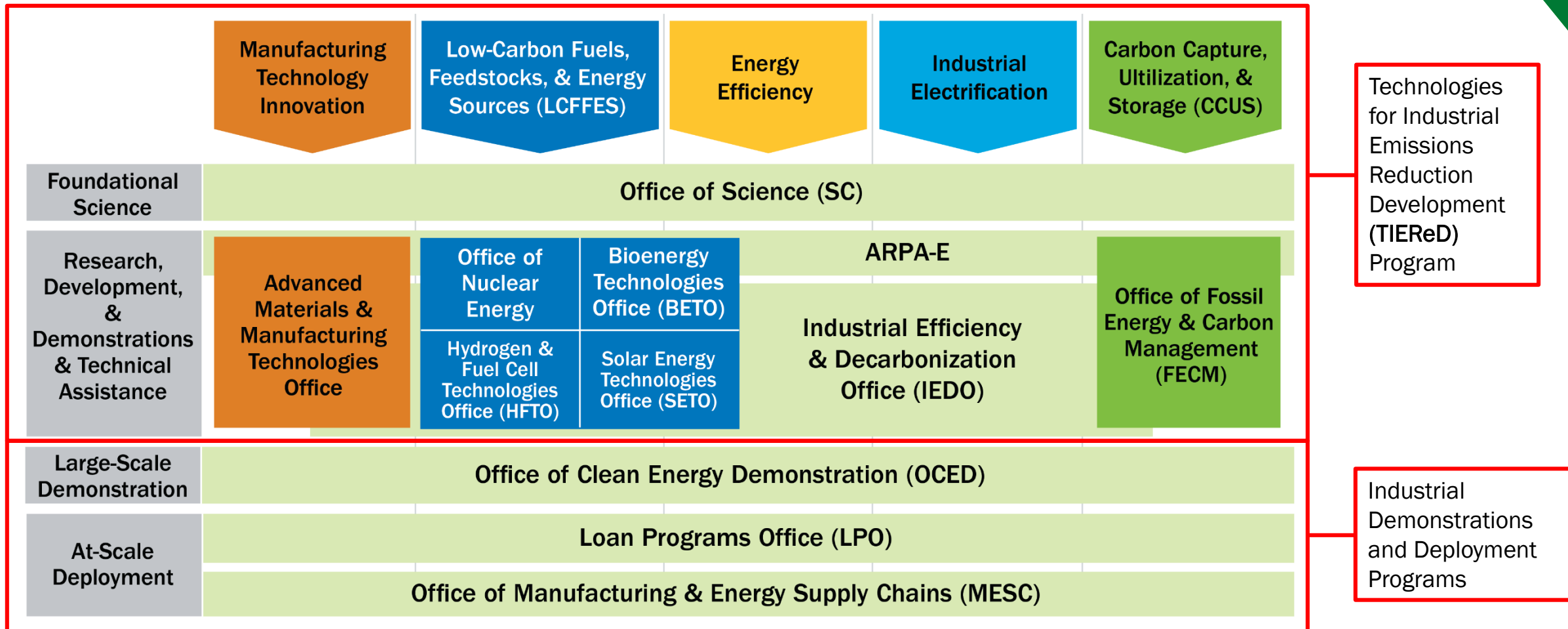


Deadline for responses was June 25, 2024

IEDO Fit within DOE Landscape



DOE Offices Share a Common Strategic Framework



www.energy.gov/industrial-technology

Industrial Demonstration and Deployment Programs

Industrial Demonstrations Program

Selections recently announced for **\$20+ billion total investment** (\$6 billion from DOE) for demonstration of transformational industrial technologies.

33 Projects in **20 states** with collective potential to

- Eliminate **14 MMT of industrial CO2** emissions annually (85% reducing criteria air pollutants)
- Create **thousands of jobs** (19 projects committed to labor unions)

Clean Hydrogen Hubs

Clean Hydrogen Hubs Program includes **\$8 billion DOE investment** to create the foundation of a nation clean hydrogen network to decarbonize the economy, including industrial sector.

7 hydrogen hubs selected last fall with collective potential to...

- Produce **3 MMT** of hydrogen annually, reaching nearly a third of the 2030 U.S. production target and **lowering emissions from hard-to-decarbonize industrial sectors**
- Reduce **25 MMT of CO2 emissions** from end-uses each year

Industrial Efficiency and Decarbonization Office (IEDO)



Energy- and Emissions-
Intensive Industries



Cross-sector Technologies



Technical Assistance
and Workforce Development



Dr. Paul Majsztik



Dr. Paul Gauche
(Acting)



Anne Hampson



Dr. Avi Shultz
Director



Dr. Paul Gauche
Deputy Director



Joe Cresko
Chief Engineer



Lauren Hall
Operations Supervisor



Ava Coy
Program Manager
Technical Project Officers



Mattie Gainer
Strategic
Communications Lead

IEDO Funding Announcements

FY22 Industrial Efficiency and Decarbonization:

- \$135M for 40 projects to decarbonize the five highest-emitting industrial subsectors

FY23 IEDO Multi-Topic:

- \$171M for 49 projects to advance high-impact applied RD&D projects to decarbonize the U.S. industrial sector. Includes sector-specific and cross-sector approaches

Decarbonization of Water Resource Recovery Facilities:

- \$27.8M for 10 projects to decarbonize the entire life cycle of Water Resource Recovery Facilities

Electrified Processes for Industry without Carbon (EPIXC) Institute

- \$70M over 5 years to bridge the gap between research and commercialization for novel electrification processes; and mobilize an innovation ecosystem of private companies, National Labs, universities, labor unions and community partners

Rapid Advancement in Process Intensification Deployment (RAPID) Institute:

- \$40M for a second 5-year phase to drive more resilient, lower cost, and reduced energy and carbon footprint manufacturing in the chemical process industries

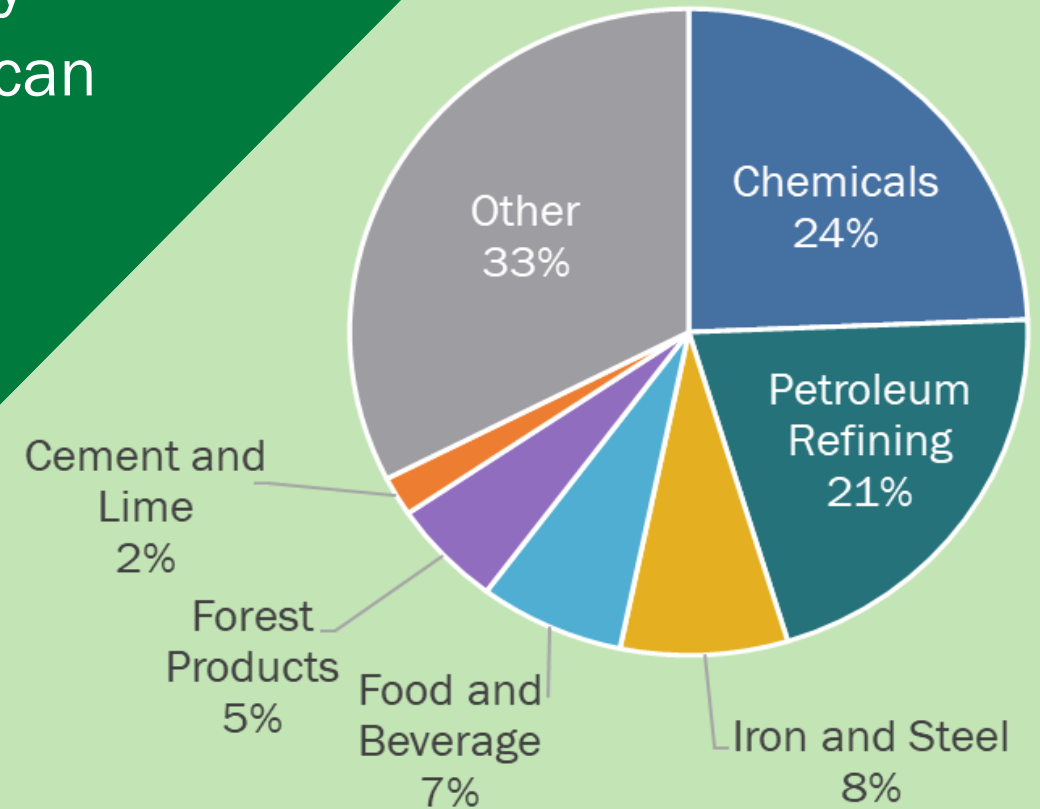
National Alliance for Water Innovation (NAWI) Hub

- \$75M for a 5-year renewal of DOE's Energy-Water Hub focused on desalination and water-treatment technologies to secure affordable and energy efficient water supplies from nontraditional water sources

\$ Half billion
over 2 years

IEDO's Research & Development Strategy

IEDO invests in both **sector-specific** technology solutions and **cross-cutting** technologies that can be applied across the industrial sector.



U.S. Manufacturing Energy-related CO₂ Emissions by Sector, 2020: 1124 MMT CO₂. Source: 2021 EIA AEO

Energy- and Emissions-Intensive Industries

IEDO accelerates the readiness of emerging, industry-specific technologies to decarbonize the most energy- and emissions-intensive industrial subsectors.



IRON AND STEEL

1,469 TBtu
100 MMT CO₂e



CHEMICALS

(including production of
low-carbon fuels)
4,842 Tbtu
332 MMT CO₂e



FOOD & BEVERAGE

1,935 TBtu
96 MMT CO₂e



FOREST PRODUCTS

2,883 TBtu
80 MMT CO₂e



CEMENT & CONCRETE

367 TBtu
66 MMT CO₂e

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

IEDO Technical Assistance & Workforce Development



Public /private partnerships to help manufacturers and industrial organizations set and achieve long-term energy intensity reduction goals



Education and training for the current and future manufacturing workforce



No-cost tools and resources for manufacturers to reduce GHG emissions and improve energy efficiency and competitiveness



End-user support, stakeholder engagement, and technical services for the industrial sector

**TA WORK PRODUCTS
INCLUDE:**

**ENERGY
ASSESSMENTS**

**PEER-TO-PEER
NETWORKING**

**TOOLS &
TRAINING**

**TECHNOLOGY
SCREENING**

**PROJECT
PROFILES**

Cross-Sector Technologies

The Cross-Sector Technologies subprogram accelerates the readiness of energy- and emissions-reducing components, systems, and operational technologies, across a broad range of industries.



**Thermal Process
& Systems**



**Low-Carbon Fuels,
Feedstocks, & Energy Sources**

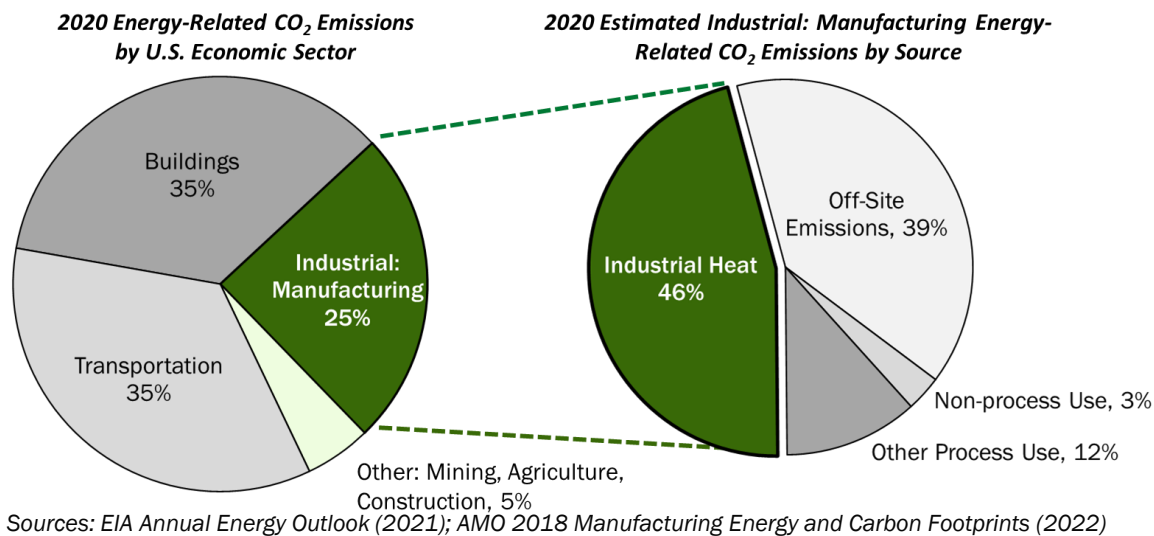


Emerging Efficiency



**Water & Wastewater
Treatment**

11% of U.S. Energy-Related Emissions are from Industrial Thermal Systems



Develop cost competitive industrial heat decarbonization technologies with at least 85% lower greenhouse gas emissions by 2035



>85% Lower Emissions



2035

Goal: Reduce the amount of heat and/or emissions from heat to make cleaner products

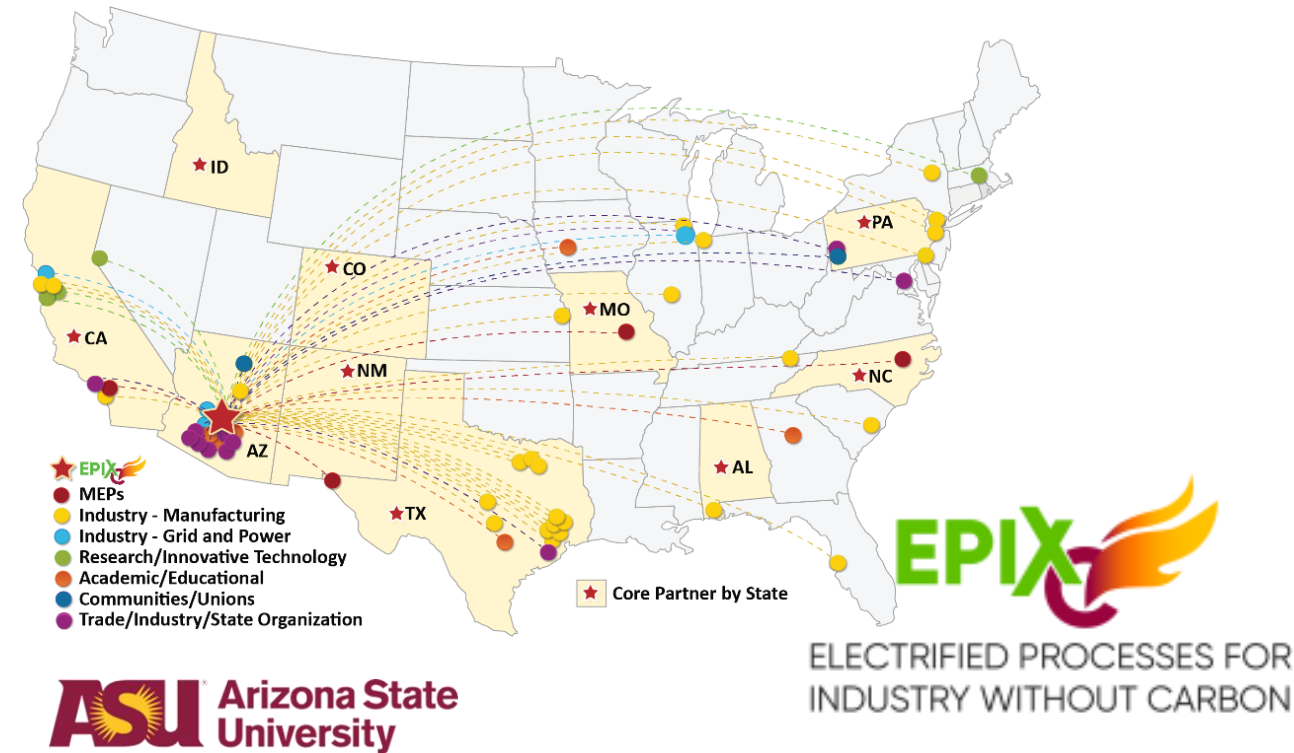
 Generate Heat from Clean Electricity	 Integrate Clean Heat from Alternative Sources	 Innovative Low- or No-Heat Process Technologies
Reduce Emissions: electrify equipment & use clean electricity, improve energy efficiency	Reduce Emissions: switch to low-emissions heat sources and increase thermal storage	Reduce Emissions: new chemistry and emerging approaches to reduce heat demand
Examples: heat pumps, microwave heating, resistive heating, etc.	Examples: solar thermal, nuclear, geothermal, hydrogen, some sustainable fuels, etc.	Examples: advanced separations, electrolysis, ultraviolet curing, biobased manufacturing, etc.

Enabling technologies and systems: e.g. energy storage, materials, modeling, data analytics, etc.

The Electrified Processes for Industry without Carbon (EPIX) Institute is DOE's 7th Clean Energy Manufacturing Innovation Institute.

EPIXC brings together >75 team members and partners representing 25 states

- Allocates up to **\$70M** in federal funding over the next 5 years to fund RD&D projects to electrify process heating.
- Mobilizes a multisector coalition of private companies, National Labs, universities, labor unions, and community partners to create an innovation ecosystem.
- Bridges the gap between research and commercialization to move novel electrification processes out of the lab and into the market.



EPIXC Key Partners:

- | | | |
|------------------------------|---|---|
| • University of Texas-Austin | • North Carolina State University | • Navajo Technical University |
| • Texas A&M University | • Missouri University of Science and Technology | • Idaho National Laboratory |
| • Penn State University | • Tuskegee University | • National Energy Technology Laboratory |
| • Stanford University | | • National Renewable Energy Laboratory |

Energy Storage to Enable Industrial Decarbonization

Industrial Energy Storage Supports Both Industrial Facilities and the Broader Energy System

Opportunities

- Reduce emissions for thermal processes through direct or indirect electrification
- Increase flexibility of industrial energy use to enable adoption of intermittent energy sources, provide grid services, and increase resilience
- Capture, store, and utilize waste heat with thermal energy storage

Key Technical Barriers

- Increase round-trip efficiency and energy density
- Develop resilient materials for high-temperature storage (TES)
- Reach industrially relevant conditions and scale
- Integrate with existing processes and infrastructure
- Achieve cost competitiveness vs. other heat/energy sources

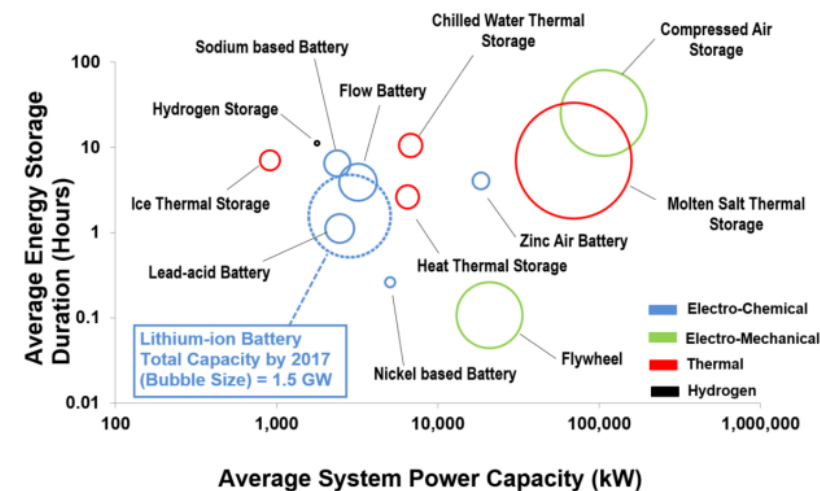


Figure 1. Average characteristics of energy storage systems built worldwide between 1958 and 2017, by technology, from the DOE Energy Storage Database (2018), sample size = 1,041 (pumped hydro not shown because of its very large global capacity)

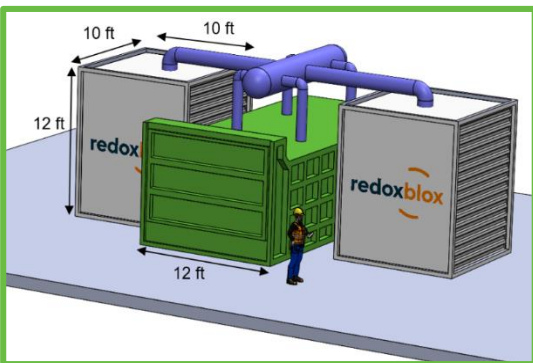
NREL: [2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark](#)



Sandia National Laboratories: [Energy StorM Workshop](#)

IEDO Thermal Energy Storage Investments

\$12M Across Diverse Portfolio to Advance Multiple Storage Modalities, Media, Scales, and Applications



Decarbonization of Steam Generation for Chemical Process Heating through Electrification and Thermochemical Energy Storage

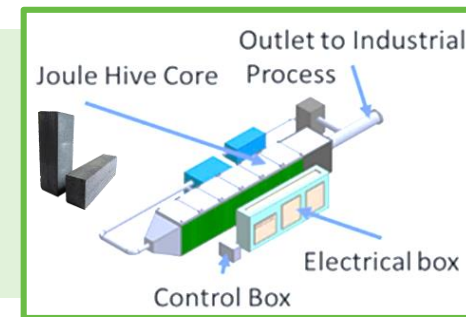
RedoxBlox | FY22 Industrial Efficiency & Decarbonization FOA | \$6,700,000

Thermochemical energy storage system using electricity to generate steam for chemicals facilities as an alternative to gas-fired steam boilers.

Joule Hive™ High Temperature Thermal Battery for Flexible Industrial Process Heat

Electrified Thermal Solutions, Inc. | IEDO FY23 Multi-Topic FOA | \$5,000,000

Sensible energy storage system that converts and stores electricity as heat at temperatures larger than 1700°C using electrically conductive firebricks.



Integrated High Operating Temperature Heat Storage System for Process Waste Heat

Advanced Cooling Technologies | FY22 SBIR/STTR | \$199,997 | Phase-Change Material

Tailored Oxide-Molten Salt (OMS) Composites for High-Operating-Temperature Thermal Energy Storage

Catalytic and Redox Solutions | FY22 SBIR/STTR | \$206,500 | Molten Salt

Coming Soon: Industrial Energy Storage System Prize!

Prize to accelerate market adoption for cost-effective energy storage concepts and technologies for industrial applications and data centers



IEDO is seeking innovative ideas using thermal energy storage in the following categories

1. Industrial cooling energy storage
2. High temperature industrial energy storage
3. Industrial thermal storage for hybrid cooling, heating, and power





**Environmental
& Health**



Economic



Societal

Technological



Beyond the Plant Bounds: Impacts and Evaluation Criteria



- Direct and indirect CO₂ emissions.
- Criteria air pollutants, toxics, other air and water pollutants, waste, thermal pollution, and land use.
- Associated health impacts.



- Equity and environmental justice.
- Energy costs and infrastructure impacting Americans
- Workforce with high-quality jobs.
- National security, critical materials, and resilient supply chains.



- Cost of abating carbon or producing a carbon-abated product.
- Cost of heat (or clean energy) or cost of material transformation.
- Deployment costs.
- Demand incentives, future regulatory or market drivers, competitiveness, and resilience.



- Energy intensity of finished products.
- Performance parameters.
- Operational factors.
- Scalability, technology or resource availability, and critical material use.
- Required expertise of workforce.

IEDO IS HIRING

Help decarbonize the
U.S. industrial sector

U.S. DEPARTMENT OF
ENERGY

Office of ENERGY EFFICIENCY
& RENEWABLE ENERGY

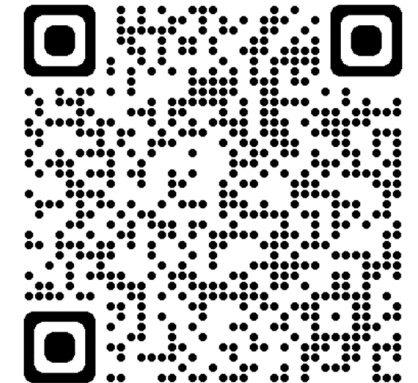
INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

Apply
Now!

Current IEDO Career Opportunities

- Cross-Sector Technologies Program Manager
- Senior Advisor on Industrial Markets

Email: IEDOJobs@ee.doe.gov



www.energy.gov/eere/iedo/iedo-careers

Fellowship Opportunity

Industrial Efficiency and Decarbonization Office

Apply Now!

Deadline August 15

Apply for IEDO's Industrial Decarbonization Fellowship to help identify key technology opportunities for the hardest-to-decarbonize industries.

As a fellow, you'll contribute to the development and execution of strategies for:

- Decarbonizing thermal processes,
- Increasing industrial energy efficiency, and
- Utilizing low-carbon fuels, feedstocks, and energy sources



Thank You!

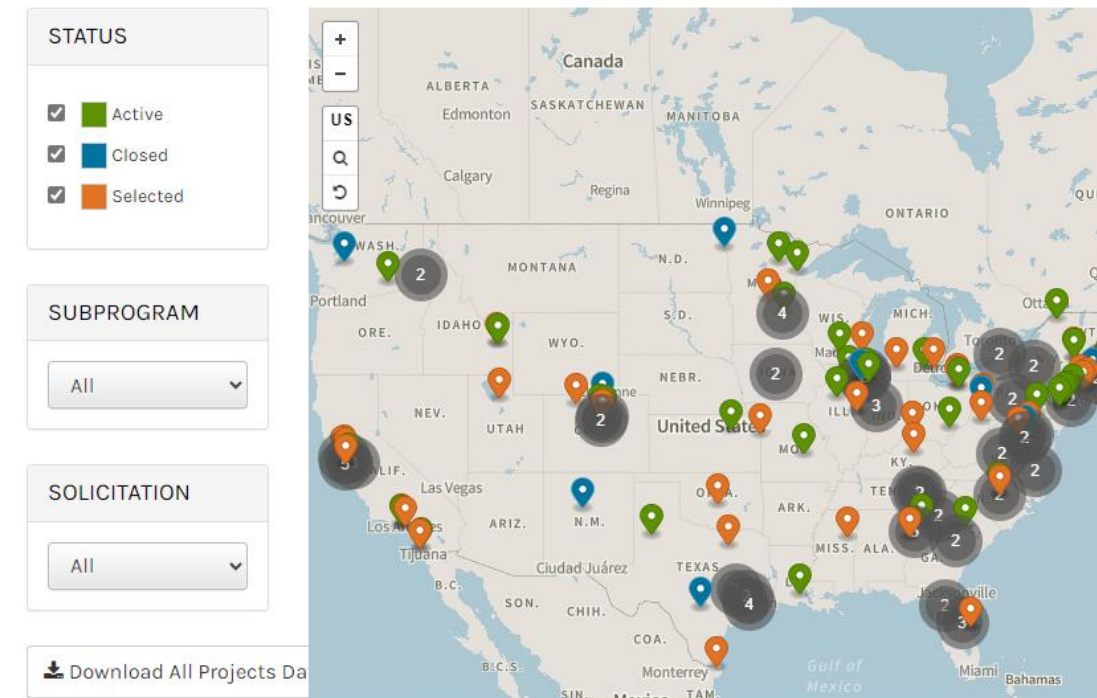
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- Announcements
- Funding opportunities
- Events
- Tool and resources
- And more!



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IEDO Project Database



www.energy.gov/eere/iedo/iedo-project-database

Industrial Technologies Joint Strategy Team



CHARTERED BY THE SECRETARY &
DEPUTY SECRETARY TO:

- 1) DEVELOP A STRATEGY
- 2) COORDINATE INTERNALLY
- 3) ENGAGE EXTERNALLY

SCOPE

Energy efficiency and decarbonization technologies that **reduce emissions and increase competitiveness** of the US industrial sector *in a net zero economy*.

INITIAL FOCUS AREAS FOR STRATEGY DEVELOPMENT

END USE SECTORS:

Metals, Chemicals, Cement

CROSS-CUTTING APPROACHES:

Energy Efficiency, Electrification

MOBILIZING
STAFF

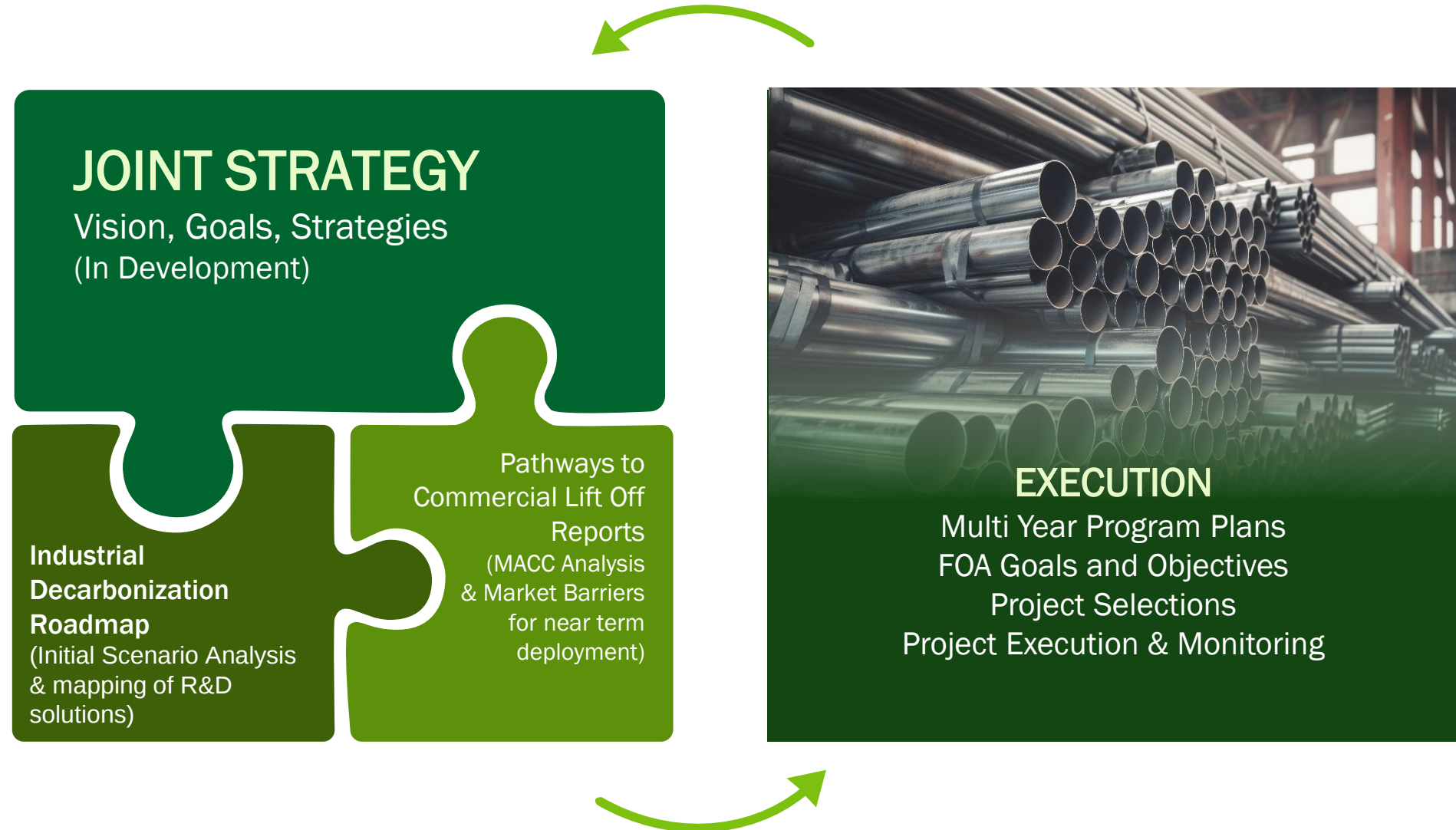


ACROSS

> **10**

OFFICES

Planning & Execution



Industrial Decarbonization Challenge by Industry

