



Overview of Industrial Efficiency and Decarbonization Research, Development, and Demonstration

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Industrial Efficiency and Decarbonization Office
US Department of Energy

NSF Workshop on Advanced Manufacturing for
Industrial Decarbonization

Arlington, VA

August 3, 2023

Building a Net-zero, Clean Energy Future

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

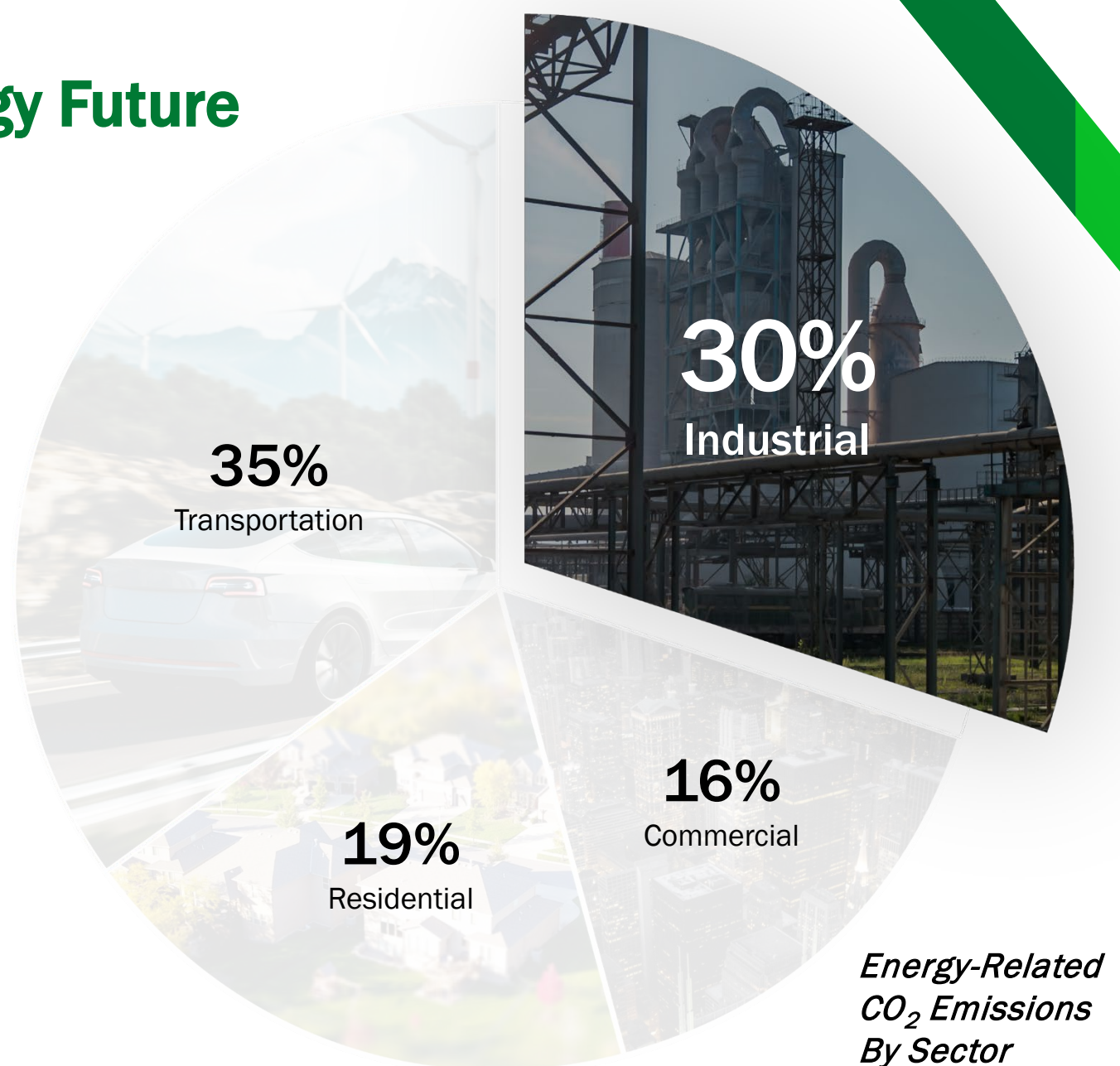
33% of the nation's primary energy use

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

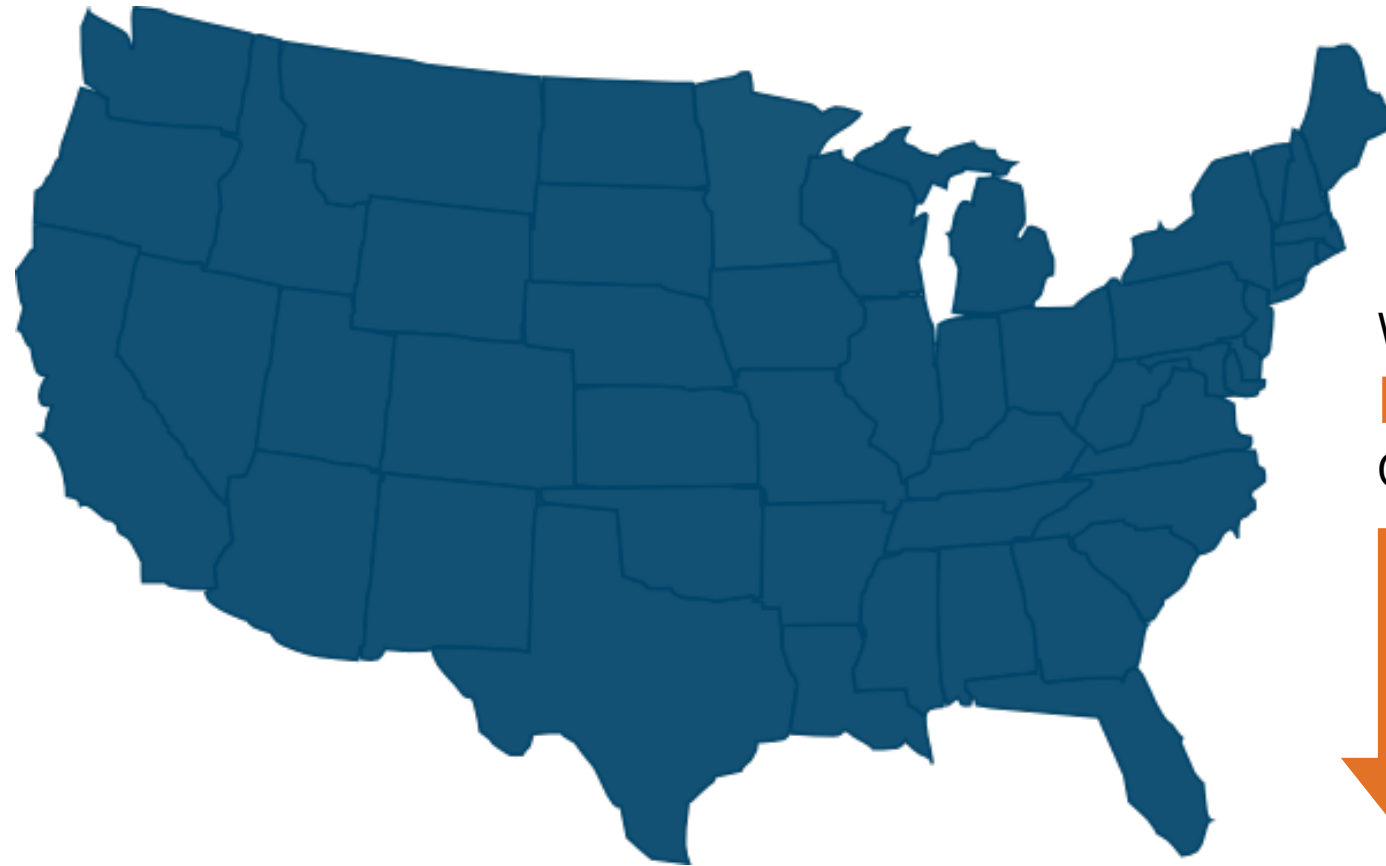
\$2.35 trillion to
the U.S. Economy

GENERATES

11% of U.S. GDP

CREATES

11.4 million jobs



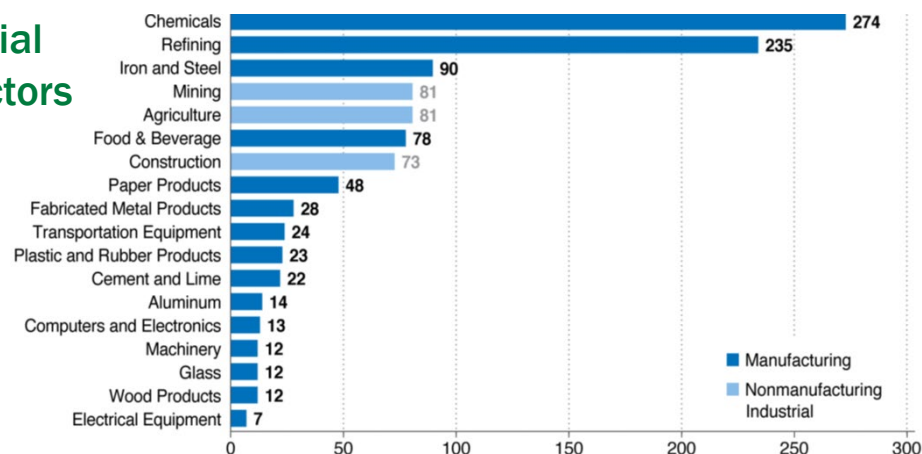
While working to
DECREASE
CO₂ emissions



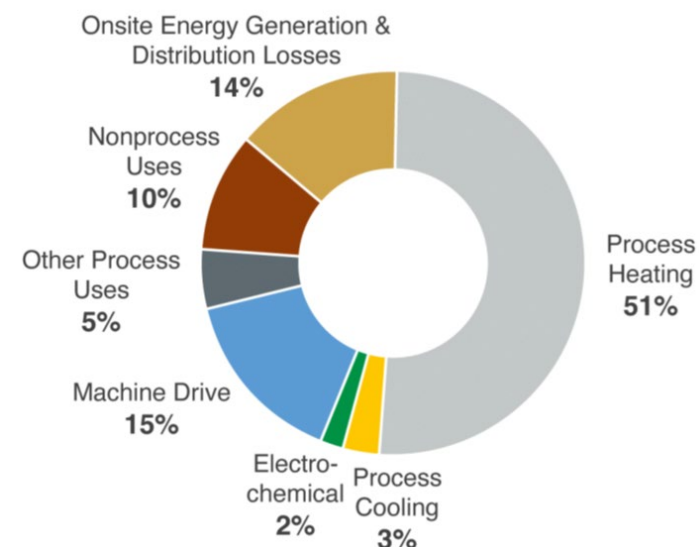
Systemic Barriers to Industrial Decarbonization

No One-Size-Fits-All Solution

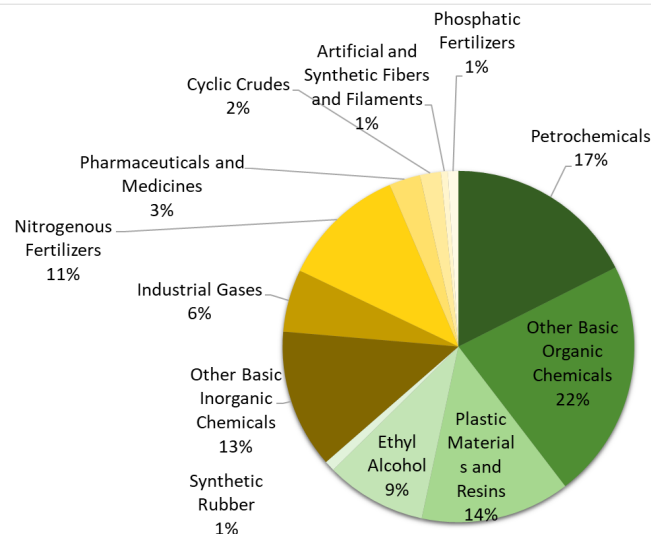
Industrial Subsectors



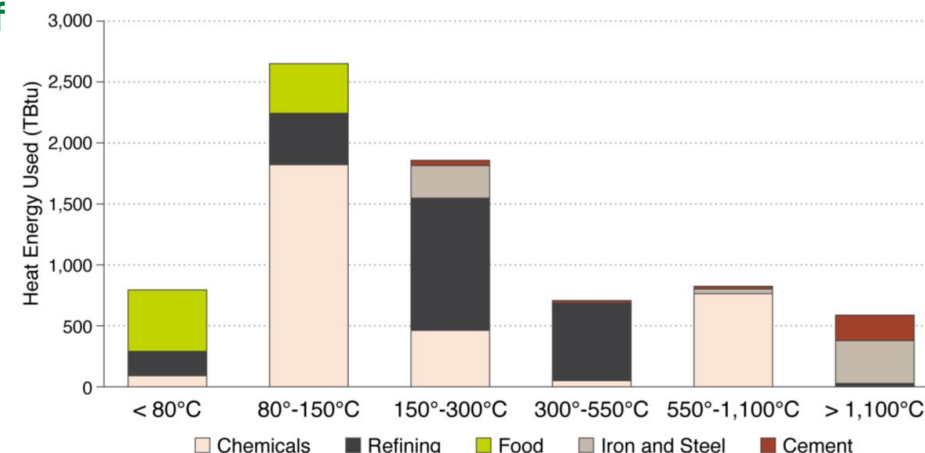
Onsite Energy Use



Chemical Products



Distribution of Process Heat



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



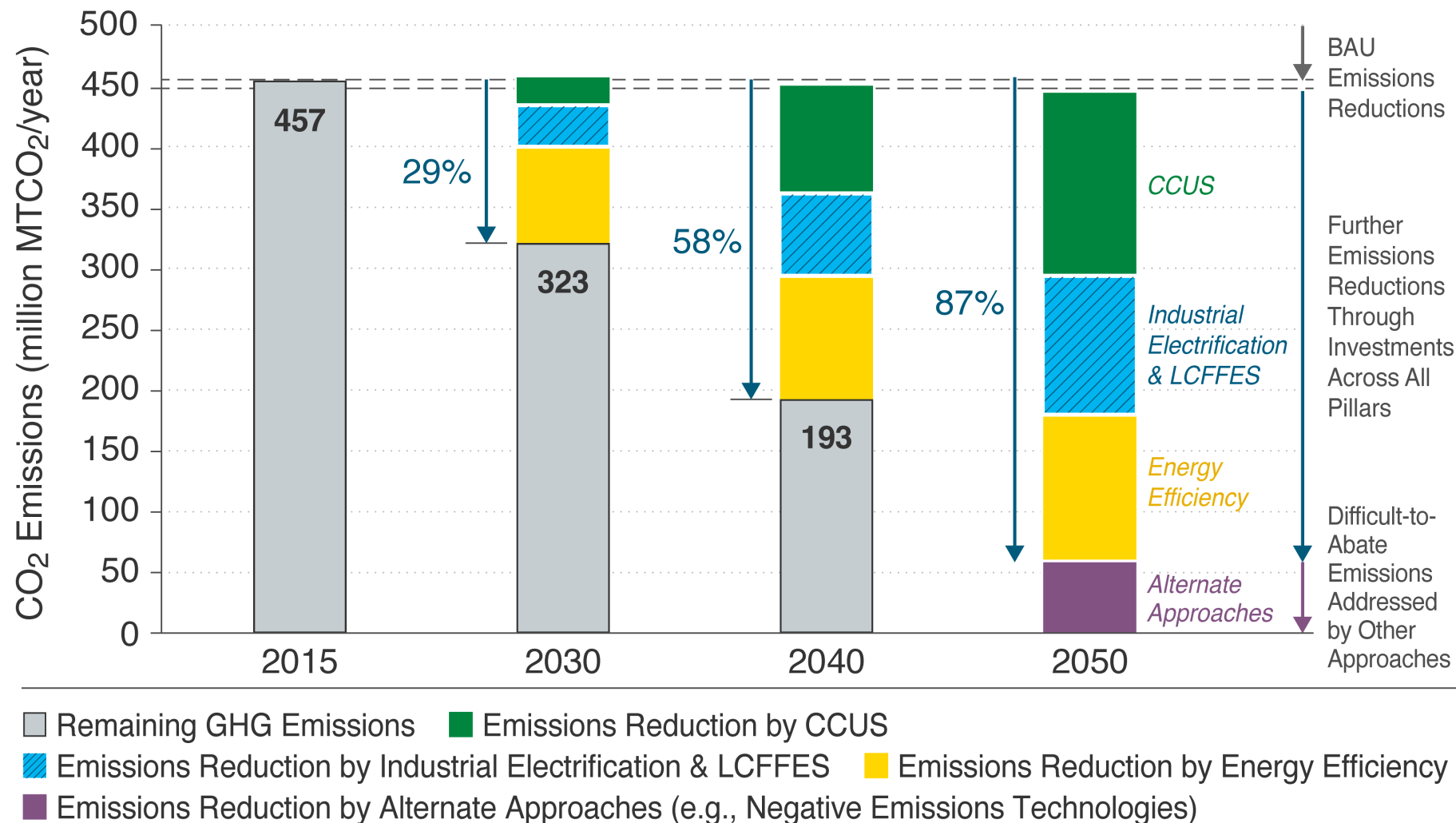
Petroleum Refining



Cement

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

Path to Net-Zero Emissions by 2050



Systemic Barriers to Industrial Decarbonization

Risk to Industry's Bottom Line

Investment scale → In the range of
\$11-21 Trillion

just for 4 sectors:



cement



steel



ammonia

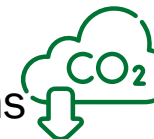


ethylene

(McKinsey, 2018)

Estimated that

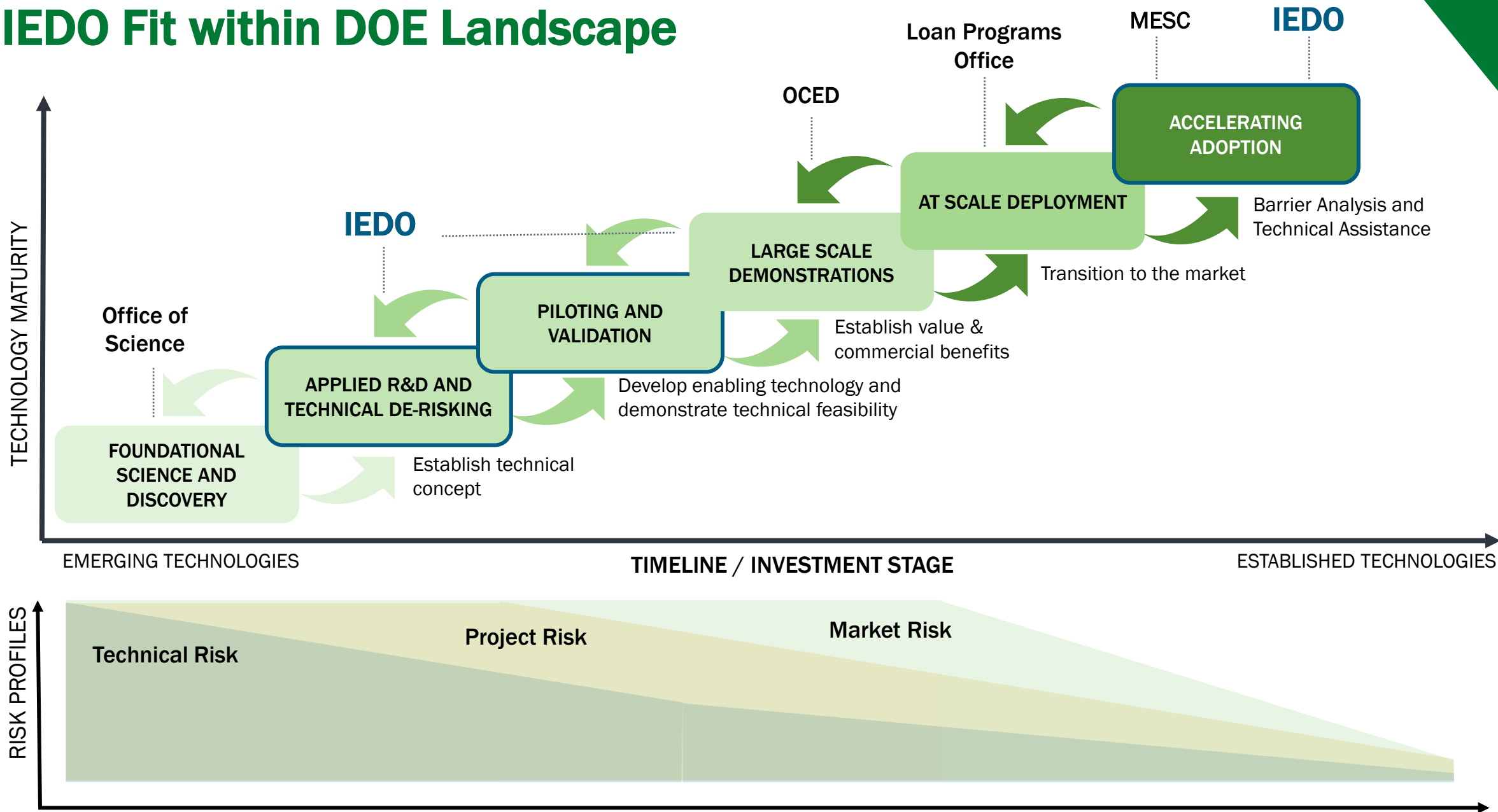
60% of heavy industry
emissions reductions



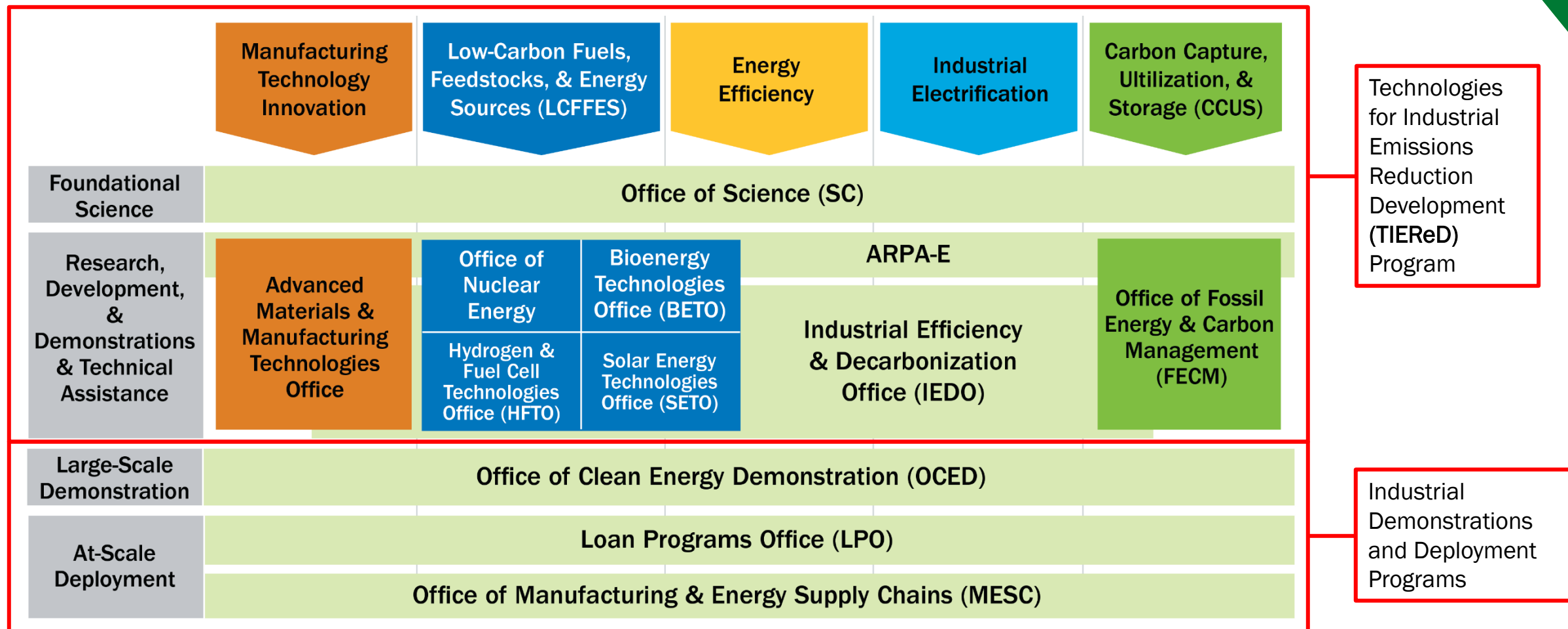
by 2050 will come from technologies
that are **not currently market ready**
(IEA, 2022)

Targeted investment for research, development,
and pilot-scale demonstrations can help U.S. industry
overcome these barriers

IEDO Fit within DOE Landscape



DOE Offices Share a Common Strategic Framework



www.energy.gov/industrial-technology/

Industrial Efficiency and Decarbonization Office (IEDO)



Energy- and Emissions-
Intensive Industries

FY23 = \$131M



Dr. Paul Majsztik



Cross-sector Technologies

FY23 = \$90.5M



Isaac Chan



Technical Assistance
and Workforce Development

FY23 = \$45M



Anne Hampson

\$266.5

Million FY23 Budget



Dr. Steven McKnight
Acting Director



Dr. Avi Shultz
Deputy Director



Joe Cresko
Chief Engineer



Lauren Hall
Operations Supervisor



Ava Coy
Program Manager
Technical Project Officers



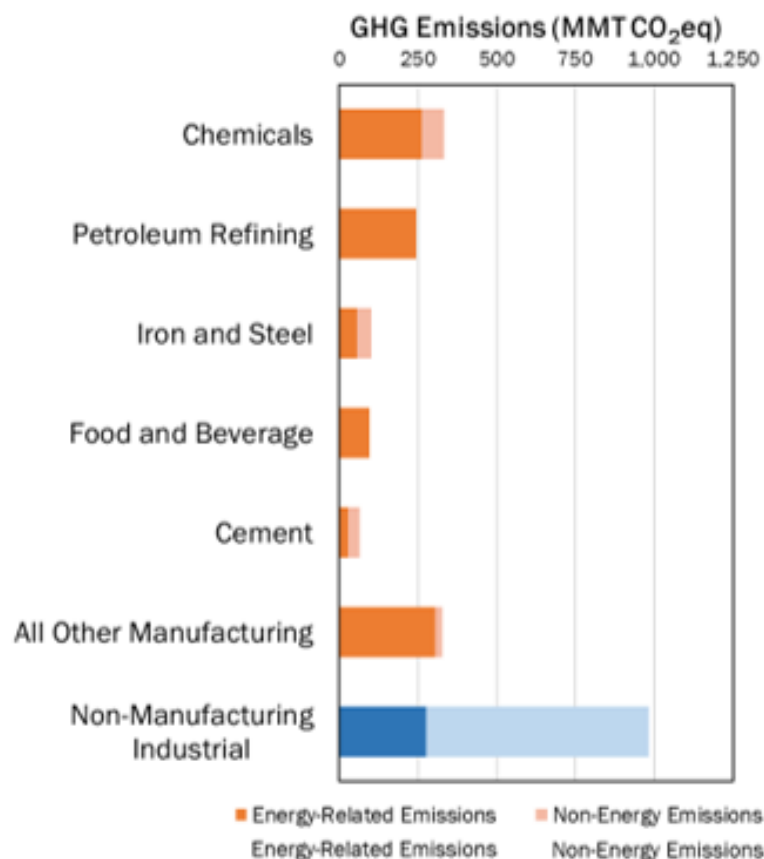
Mattie Gainer
Strategic
Communications Lead

Energy- and Emissions-Intensive Industries

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



Dr. Paul Majsztrik
Program Manager



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

EIA Monthly Energy Review, Manufacturing Energy Consumption Survey; EPA GHGRP Inventory, DOE [Manufacturing Energy and Carbon Footprint](#),

IEDO Priorities

Chemicals/Refining	Iron and Steel	Cement and Concrete	Food and Beverage	Forest Products
Sustainable Feedstocks (especially carbon)	Alternative reductants - hydrogen, ammonia for DRI/HBI; biomass for solid pig iron	Alternative binders and process routes to OPC	Low-carbon fuels or electrification for steam boilers	Increase biomass utilization
Low Carbon Fuels	Molten ore processing – molten oxide electrolysis; hydrogen plasma direct smelting	Carbon capture from limestone decarbonation	Low-temperature waste heat recovery from process exhausts	Low-carbon fuels for lime kilns
Low Carbon and Electrified Process Heating	Carbon Capture and Storage on Existing BF/BOF facilities	Clinker Substitutes	Alternative protein products	Low-carbon fuels or Electrification for steam boilers
Electrochemical reactors	Electrowinning - molten salts; aqueous	CO ₂ mineralization	Smart/Flexible manufacturing processes	Energy efficient separations for concentrating liquor
Waste heat recovery	Low-carbon fuels and electrification for process heating, reheats	Waste heat recovery	Drying and dewatering innovations	Process Electrification
Carbon capture integration	Waste heat recovery	Electrification & low carbon fuels	Waste management and reduction	Carbon capture integration with boilers
High efficiency thermal reactors		Alternative building materials	Innovative cooling, refrigeration and freezing solutions	Drying and dewatering innovations
Advanced separations			Wastewater Recovery and Reuse	Increase fiber yield of pulping
Material reuse				Increasing solids content in paper forming

IEDO Priorities

Crosscutting: Carbon Capture, Utilization, and Storage (CCUS)



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IEDO Priorities

Crosscutting: Low-Carbon Fuels and Electrified Heating



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IEDO Priorities

Crosscutting: Energy and Materials Efficiency



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IEDO Priorities

Crosscutting: Water Treatment and Management



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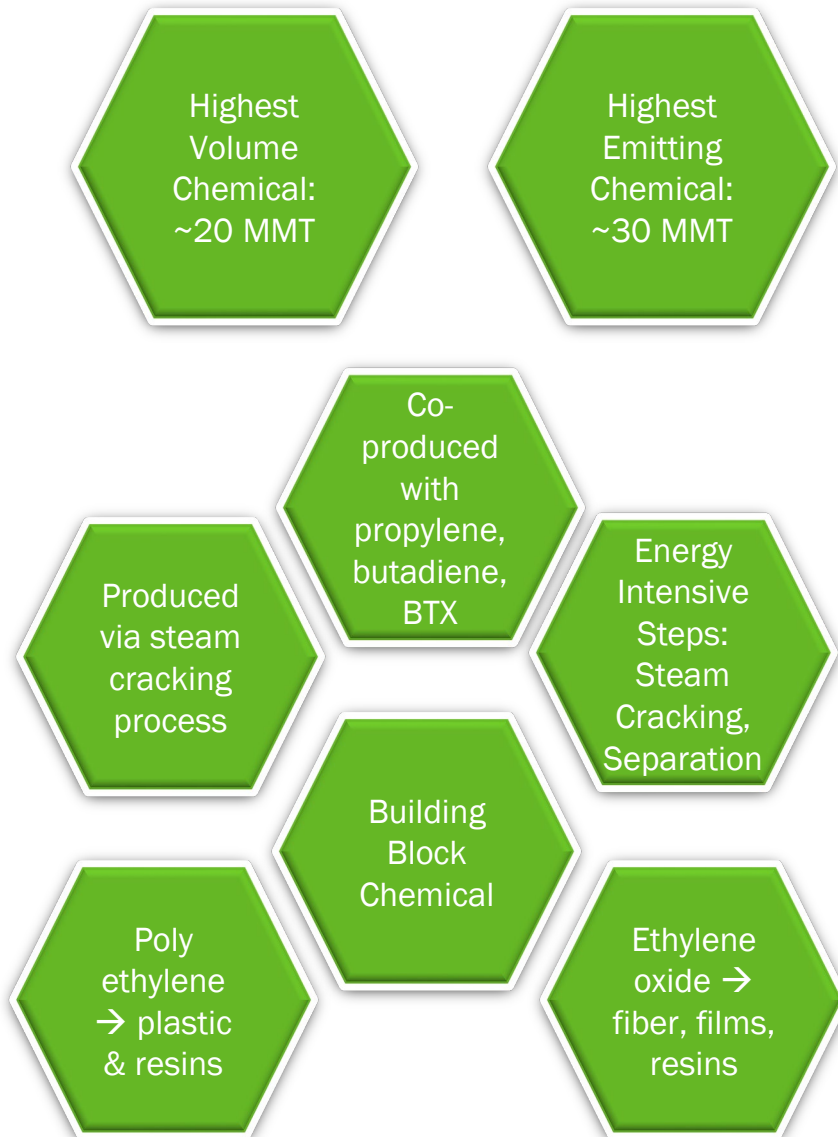
IEDO Priorities

Sector-Specific Innovations



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Chemicals Example: Decarbonization of Ethylene



Decarbonization Pathways

Feedstock

- CO₂ via thermal or electrochemical pathways
- Biomass via thermal or enzymatic pathways
- CH₄ via oxidative coupling of methane
- Material reuse, plastic upcycling

Process Heating: Steam Cracking


- Electrification of steam cracker via electrified steam, rotary olefin cracker
- Electrochemical CO₂ conversion
- Photocatalytic conversion

Process Heating: Separations

- Membranes (non-thermal separations)
- Avoid separations through optimized selectivity

Reduced Demand

- Direct conversion of feedstock to end product



>85% net
reduction vs.
fossil-based
sources



2050 Resource Supply



1,050 MMT
biomass and
waste



450 MMT
CO₂



...can be converted into...



>400 MMT*
fuels and chemicals

*This Shot assumes that 50% of marine, rail, off-road, hydrocarbon chemicals and 100% of aviation demand will be met by hydrocarbon fuels in 2050.

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.



Isaac Chan
Program Manager



**Thermal Process
& Systems**



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



Emerging Efficiency



**Water & Wastewater
Treatment**

Tackling Emissions from Industrial Heat Across the Industrial Sector

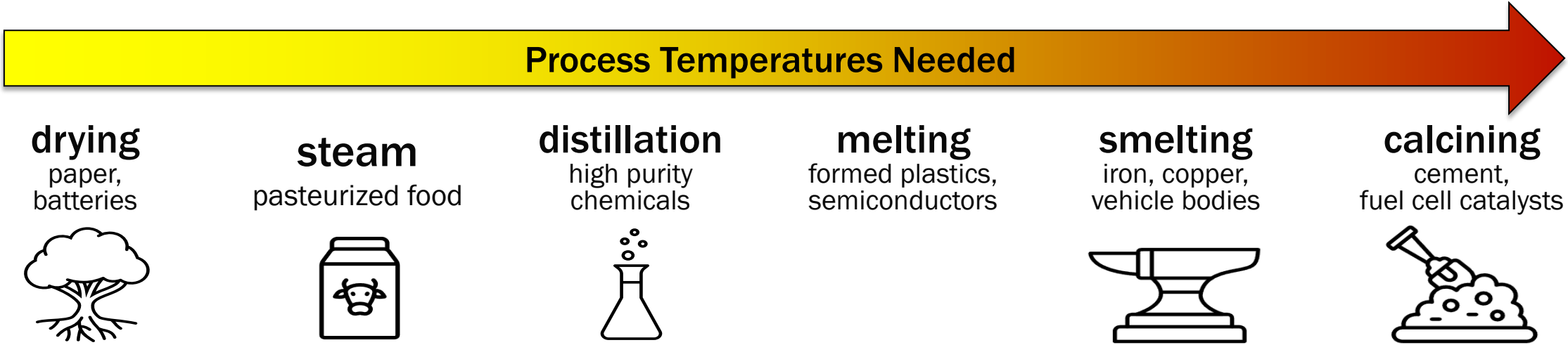
Develop cost competitive industrial heat decarbonization technologies with:



> 85% Lower Emissions



2035



IEDO Activities in support of the Industrial Heat Shot



Generate Heat
from Clean Electricity

Electrification of Process Heat: Develop and support innovation ecosystem to accelerate development and deployment of eletrotechnologies, including heat pumps



Innovative Low- or No-Heat
Process Technologies

Priorities include low thermal budget processes and no-heat separation technologies



Integrate Clean Heat
from Alternative Sources

Priorities include thermal energy storage, low-carbon fuels, such as hydrogen and bio-based

Arizona State University to Lead New DOE Institute Focused on Electrifying Process Heat

- The Electrified Processes for Industry without Carbon (EPIX) Institute is DOE's 7th Clean Energy Manufacturing Innovation Institute.
- EPIX will:
 - Allocate up to \$70M in federal funding over the next 5 years to fund RD&D projects to electrify process heating.
 - Mobilize a multisector coalition of private companies, National Labs, universities, labor unions, and community partners to create an innovation ecosystem.
 - Bridge the gap between research and commercialization to move novel electrification processes out of the lab and into the market.



ELECTRIFIED PROCESSES FOR
INDUSTRY WITHOUT CARBON



IEDO's Technical Assistance Efforts

Technical Assistance: Partners with and enables industry to accelerate the adoption of technologies, programs, and best practices that improve efficiency and decarbonization.

Workforce Development: Promotes the development of a diverse mix of new workers and upskills existing workers for the industrial jobs of today and the future.



Anne Hampson
Program Manager



Public /private partnerships to help industrial organizations set and achieve 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

PROGRAMS INCLUDE: ONSITE ENERGY | PROGRAM 50001 | READY & SEP 50001 | WORKFORCE DEVELOPMENT

Why Companies Join Better Plants

Market Leadership

Developing Innovative, Replicable Solutions with Market Leaders

- National Recognition
- Peer to Peer Networking
- Better Building Solutions Center

Technical Assistance

Making Energy Efficient Investments Easier

- Technical Account Managers
- Software tools for energy management and analysis
- Financing Navigator
- Diagnostic Equipment Program
- Technical Publications

Access to Innovation

Innovation to Drive Savings

- DOE National Lab Visits
- Industrial Technology Validation

Workforce Development

Helping You Meet Your Challenges of Today, and Tomorrow

- In-Plant Trainings
- Virtual trainings
- Energy and Decarbonization bootcamps



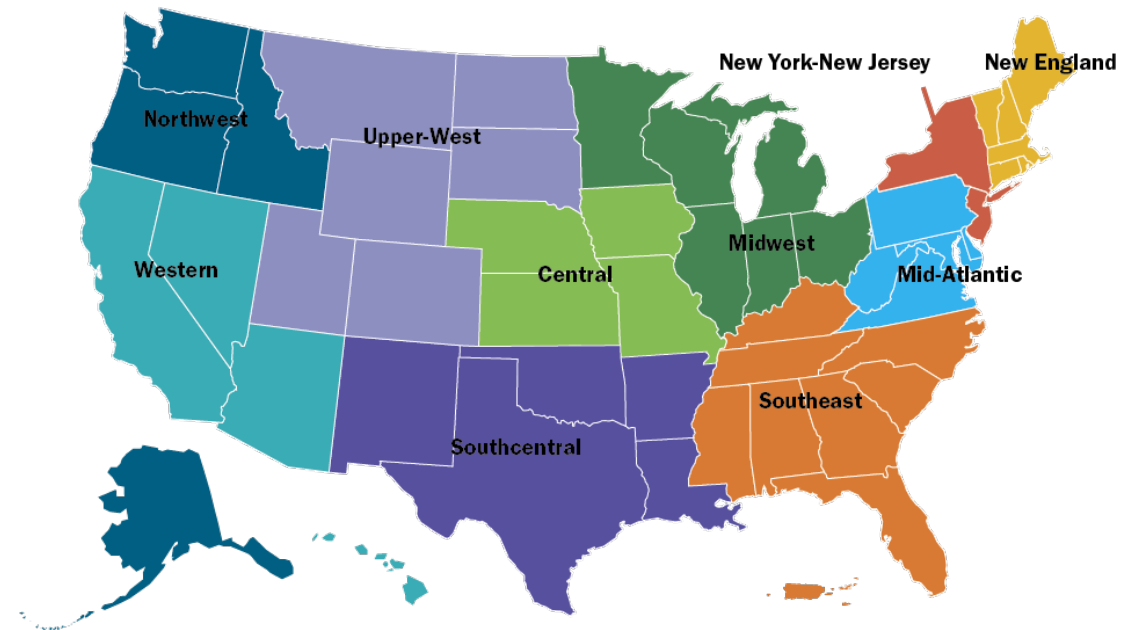
IEDO Onsite Energy Program

The Onsite Energy Program is a new initiative to provide technical assistance for industrial facilities and other large energy users to increase the adoption of onsite clean energy technologies.

battery storage | combined heat and power | district energy | geothermal |
industrial heat pumps | renewable fuels | solar PV | solar thermal | thermal storage | wind

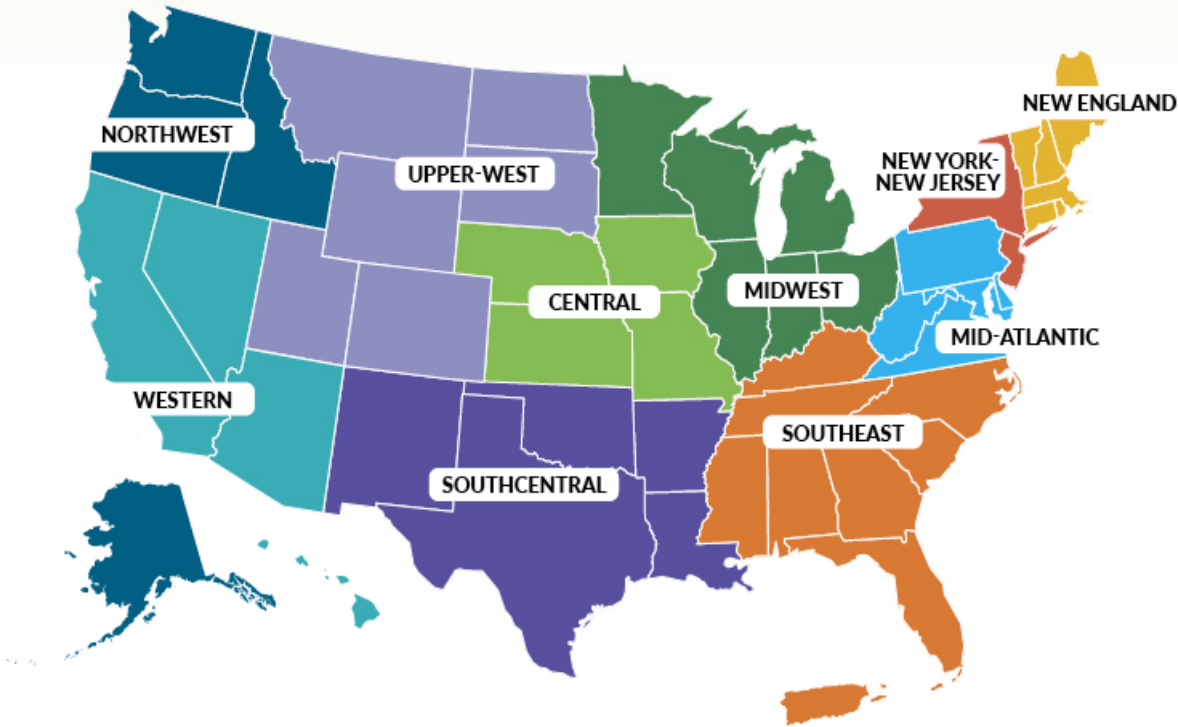
The Onsite Energy Program will establish a regional network of Technical Assistance Partnerships (TAPs) to help:

- Deploy onsite renewable energy and storage technologies
- Identify cost-effective options for achieving clean energy targets
- Highlight pathways for accelerating the integration of onsite clean energy technologies
- Reduce greenhouse gas emissions while prioritizing energy justice and workforce development



DEPARTMENT OF ENERGY SELECTS

Nine Organizations to Implement Onsite Energy Technical Assistance Partnerships to Decarbonize America's Industrial Sector



Northwest

AK, ID, OR, WA

Washington State University
Energy Program

Midwest

IL, IN, MI, MN, OH, WI

University of Illinois Chicago

New York-New Jersey

NY, NJ

Pennsylvania State University

Western

AZ, CA, HI, NV

Optony Inc.

Central

IA, KS, MO, NE

University of Illinois Chicago

New England

CT, MA, ME, NH, RI, VT

University of New Hampshire

Upper-West

CO, MT, ND, SD, UT, WY

Cascade Energy, Inc.

Southeast

AL, FL, GA, KY, MS, NC, PR, SC, TN, VI

North Carolina State University

National Selection

University of Connecticut

Southcentral

AR, LA, NM, OK, TX

Houston Advanced Research
Center

Mid-Atlantic

DC, DE, MD, PA, VA, WV

Pennsylvania State University



U.S. DEPARTMENT OF
ENERGY

Office of ENERGY EFFICIENCY
& RENEWABLE ENERGY

INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

Industrial Efficiency and Decarbonization FOA

Announced June 15: 40 Projects Across 21 States Will Advance Technologies to Decarbonize American Industry and Help Create Good-Paying Jobs

- Decarbonizing Chemicals (*9 projects, \$38.3 million*)
- Decarbonizing Iron and Steel (*10 projects, \$31.9 million*)
- Decarbonizing Food and Beverage Products (*3 projects, \$11.4 million*)
- Decarbonizing Cement and Concrete (*5 projects, \$16.4 million*)
- Decarbonizing Paper and Forest Products (*6 projects, \$16.2 million*)
- Cross-Sector Decarbonization Technologies (*7 projects, \$20.4 million*)

Full project descriptions here: <https://www.energy.gov/eere/iedo/funding-selections-industrial-efficiency-and-decarbonization-foa-0>

Fiscal Year 2023 Multi-topic FOA

March 2023: IEDO Announced \$156 Million for Applied Research and Development Projects to Drive Industrial Decarbonization

The FOA builds on the findings from the Industrial Decarbonization Roadmap and seeks projects in multiple topics:

- Topic 1: Decarbonizing Industrial Heat
- Topic 2: Low-Carbon Fuels Utilization RD&D
- Topic 3: Exploratory Cross-Sector R&D
- Topic 4: Decarbonizing Chemicals
- Topic 5: Decarbonizing Iron and Steel
- Topic 6: Decarbonizing Food and Beverage Products
- Topic 7: Decarbonizing Cement and Concrete
- Topic 8: Decarbonizing Forest Products



Mandatory Concept Papers Due:

April 17, 2023

Full Applications Due:

June 23, 2023

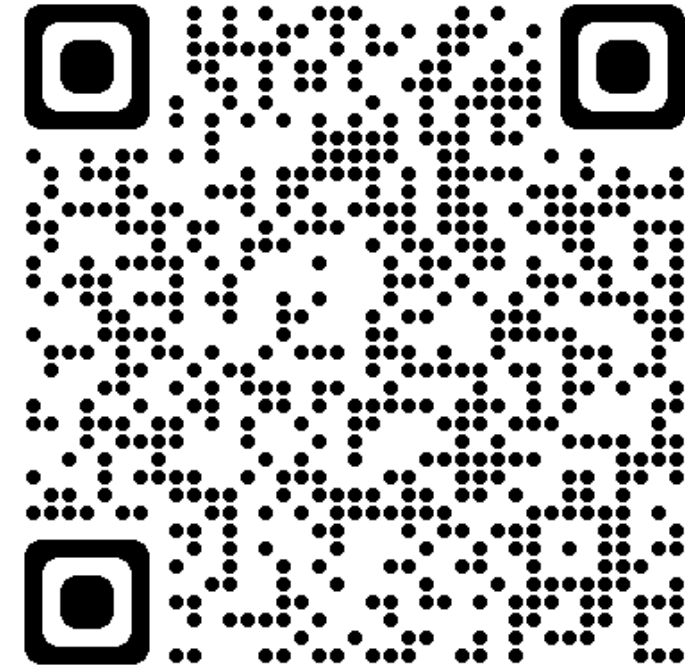
Selections Anticipated:

September 2023

IEDO is Hiring - Join Our Team!

Current IEDO Career Opportunities

- Cross-Sector Industrial Decarbonization Technologies Technology Manager (Process Heating)
- Energy- and Emissions Intensive Industries Sr. Technology Manager (Iron/Steel)
- Energy- and Emissions-Intensive Industries Technology Manager (Cement/Concrete)
- Technical Assistance and Workforce Development Technology Manager



Interested in applying?

Visit our careers page or scan the QR code:

<https://www.energy.gov/eere/iedo/iedo-careers>

Email: IEDOJobs@ee.doe.gov

Thank You!

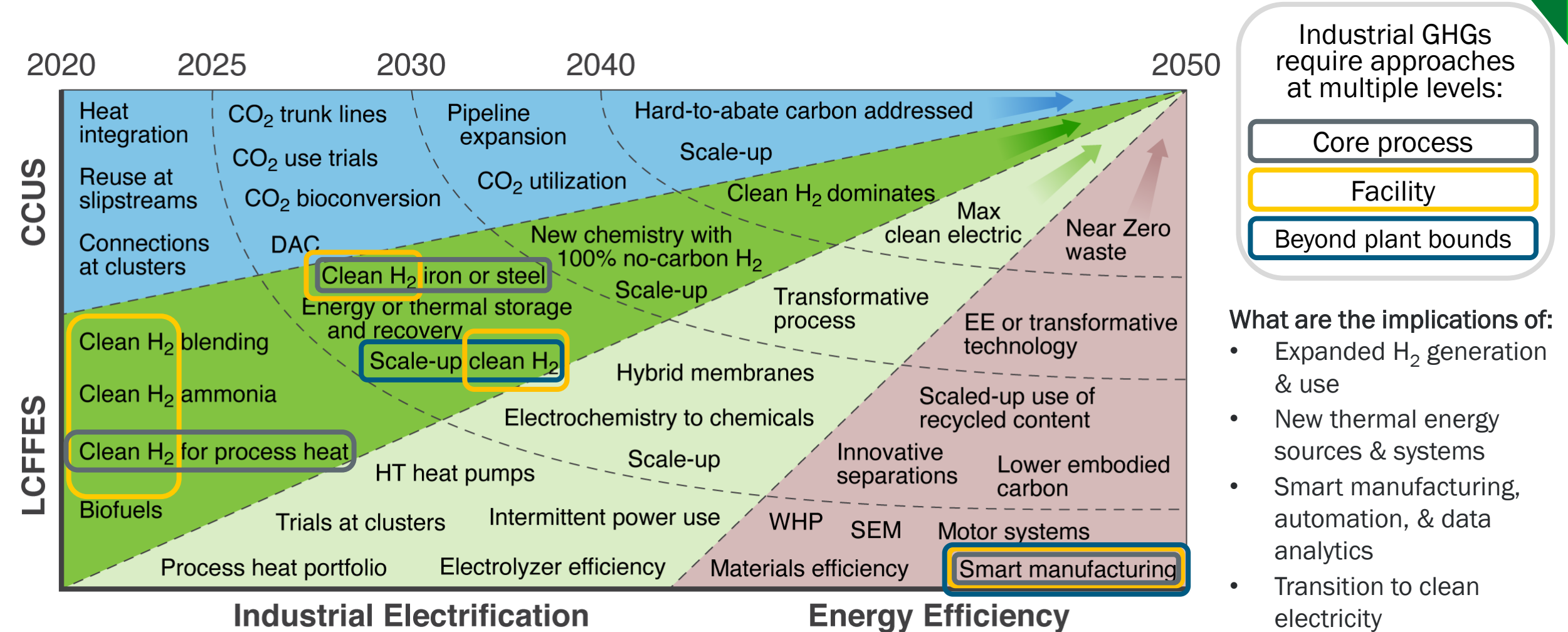
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- Funding opportunities
- Events
- Tool and resources
- And more!

To sign up visit: <https://www.energy.gov/eere/iedo/subscribe-iedo-newsletter>



Industrial Decarbonization is also a systems challenge



Landscape of major RD&D investment opportunities for industrial decarbonization between now and 2050.

LCFFES = Low Cost Fuels, Feedstocks, and Energy Sources; CCUS = Carbon Capture Utilization and Storage

Source: [Industrial Decarbonization Roadmap](#)

Overview of 48C Round 1 (2023)

What is the Qualifying Advanced Energy Project 48C Credit?

- Competitively-awarded Investment Tax Credit (ITC) established in 2009 and functions very similar to FOA
- Expanded by IRA with **\$10B** for (1) clean energy manufacturing & recycling, (2) critical materials, and (3) industrial GHG emissions reduction projects
- Projects receive 30% ITC (or 6% if prevailing wage and apprenticeship requirements not met)
- DOE will accept a first round of applications in 2023 to allocate up to \$4B, with additional competitive application rounds in future years
- Approximately 40% of credits (\$1.6B) will be allocated to projects in coal communities (if sufficient meritorious applications are received)

Legend

- Scope defined by ARRA in 2009
- Scope added by IRA

Clean Energy Manufacturing and Recycling

- Re-equip, expand, or establish Industrial or manufacturing facility for production or recycling of clean energy and energy efficiency technologies

Critical Materials Processing, Refining, and Recycling

- Re-equip, expand, or establish an industrial facility to process, refine, or recycle critical materials (50 USGS minerals + DOE critical materials)

Industrial GHG Emissions Reductions

- Re-equips industrial or manufacturing facility to reduce greenhouse gas emissions by at least 20%

Timeline and Review

- **Notice Released:** May 31
- **Informational Webinar:** June 27
- **Concept Papers Due:** July 31
- **Full Applications Due:** Fall 2023

DOE will evaluate proposals against technical review criteria reflecting four major priority measures, and pass recommendations to Treasury:

1. Commercial Viability
2. Greenhouse Gas Emissions Impacts
3. Strengthening U.S. Supply Chains and Domestic Manufacturing for a Net-Zero Economy
4. Workforce and Community Engagement

With merit review scores plus program policy factors DOE will rank all meritorious projects into a final list for up to \$4 billion in allocations for IRS

Allocation Decisions: No later than March 31, 2024



Program Update: Industrial Demonstrations Program

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

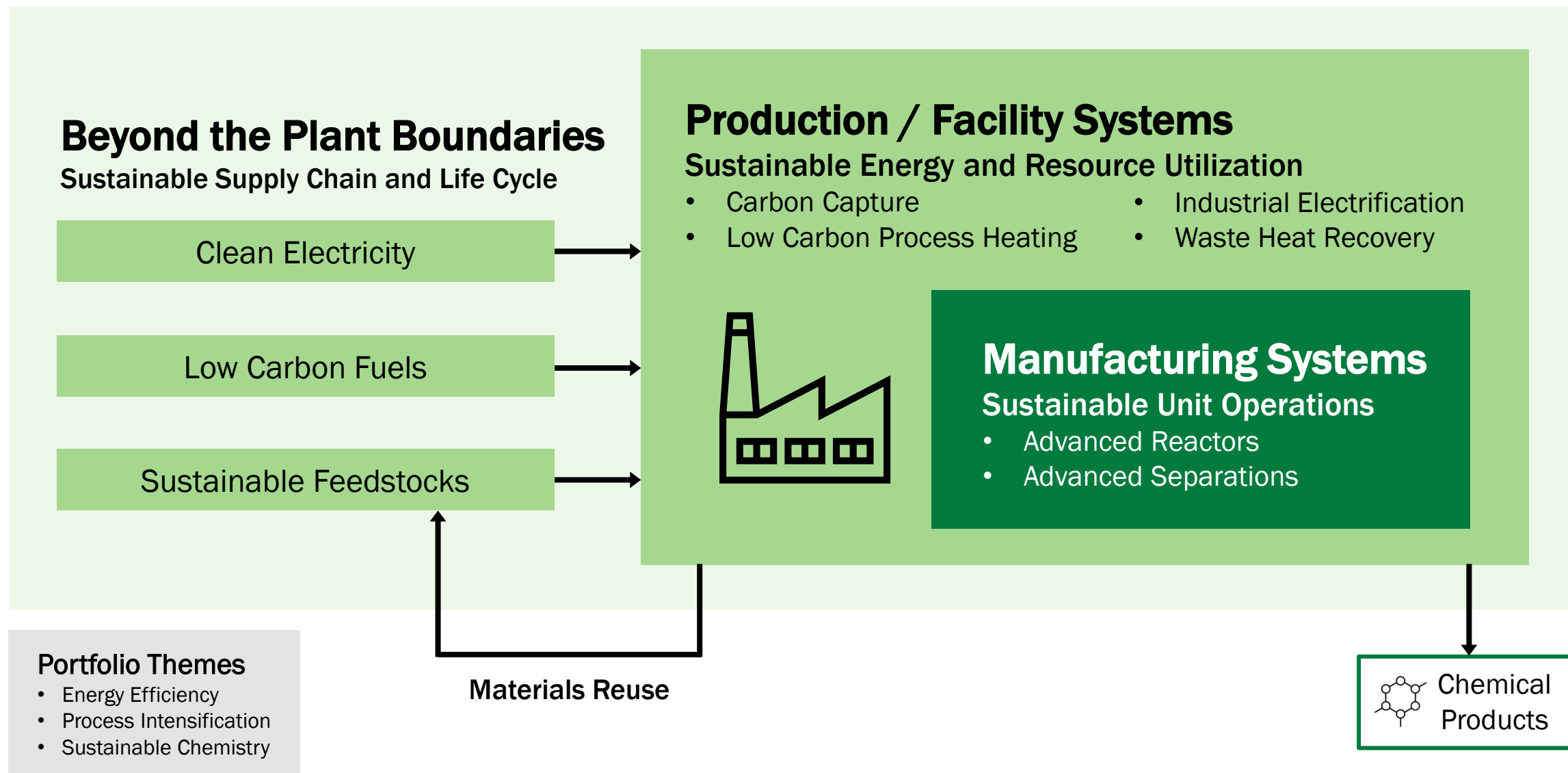


Winter 2023/2024
Selections Announced

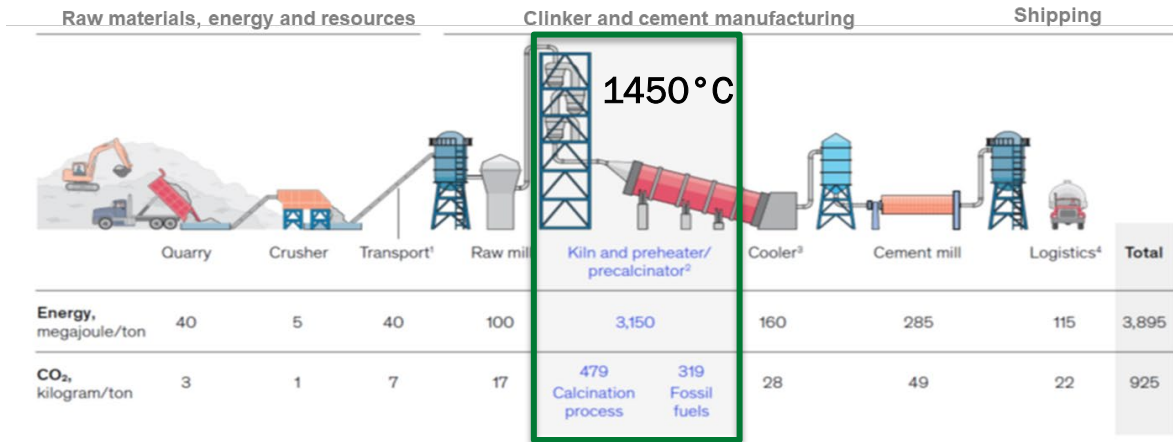


OCED
Office of Clean Energy Demonstrations

IEDO Strategies for Chemicals Sector Decarbonization



Cement and Concrete Example



Feedstocks

- Cement Clinker: Limestone (CaCO₃) + Sand/Clay/Shale (**local**)
- Concrete: Cement, sand, gravel, water (**local materials**)
- Fuel: Coal/waste oil/tires/trash (kiln heating)

Cement (Clinker) Process

- Limestone calcination (CaCO₃ → CaO + CO₂)
- High-temperature pyro-process (1450°C) to form cement phases
- Process emissions (~60%) and fuel (~40%) → ~90% of cement CO₂

Decarbonization Pathways

Cement/concrete formulation

- Replace clinker with SCMs & fillers (mineral substitutes)
- Alternative cement formulations (limestone calcined clay)
- Concrete mix design optimization

Cement Process

- Alternative fuels/electric (doesn't address process emissions)
- Alternative chemical process
- CCUS

Alternative Cement/Binder

- Novel alternative cement chemistry & raw materials

CO₂ Mineralization

- CO₂ cured concrete & SCMs

Better Plants Impact

280+ partners
> 3,500 facilities
74 goals achieved



2.2 QBTU
of energy saved



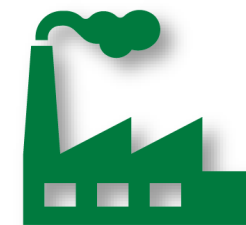
1.8%
average annual
energy intensity
improvement rate



\$10.6 billion
saved



131 million
metric tons of CO₂ saved



14%
of the U.S.
manufacturing footprint