

# Challenges, Priorities and Opportunities for Industrial Heat Pumping Technologies

Yaroslav Chudnovsky, Ph.D., MBA, Senior Technology Manager, Energy and Emissions Intensive Industries  
Industrial Efficiency and Decarbonization Office

2023 ACEEE Industry Summer Study - Industrial Heat Pumps Workshop

Detroit, MI, July 11, 2023



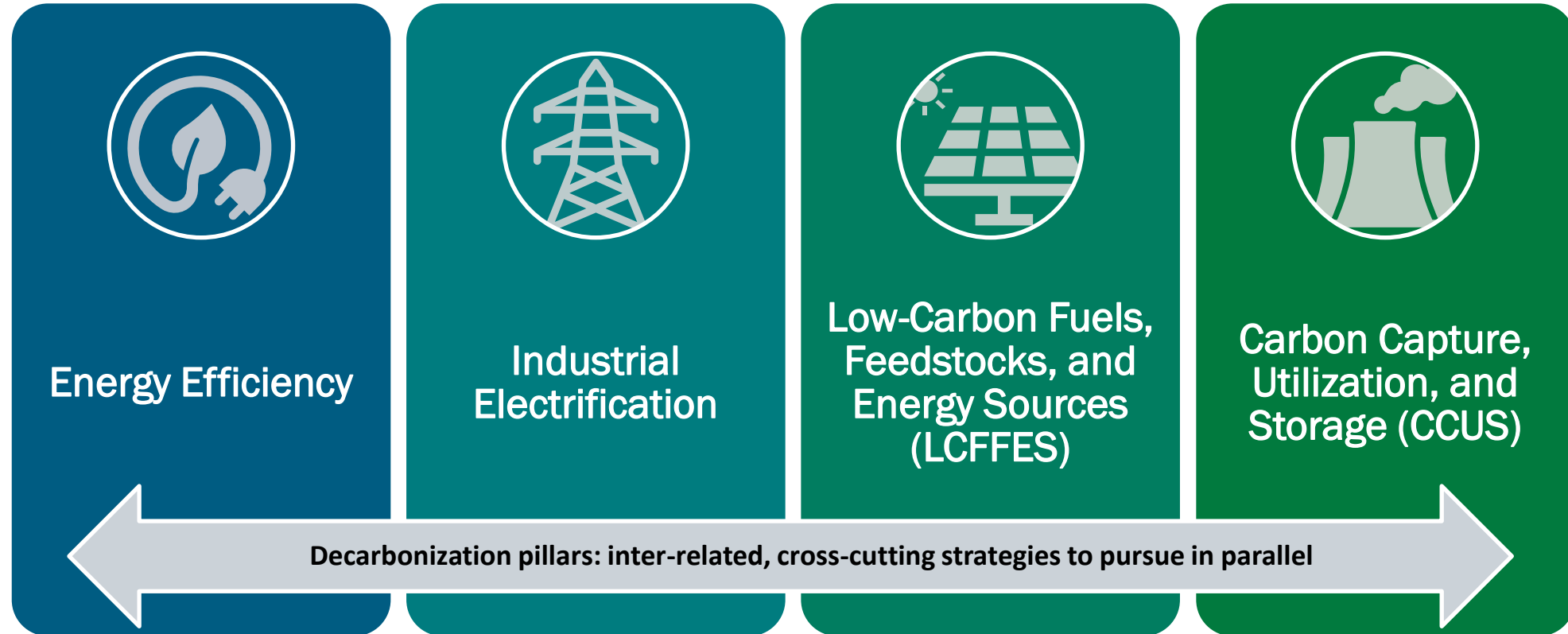
# The IEDO Mission

Lead the development and accelerate the adoption of sustainable technologies that increase efficiency and eliminate industrial GHG emissions



# U.S. DOE Industrial Decarbonization Roadmap

## Industrial Decarbonization Pillars



Iron & Steel



Chemicals



Food & Beverage

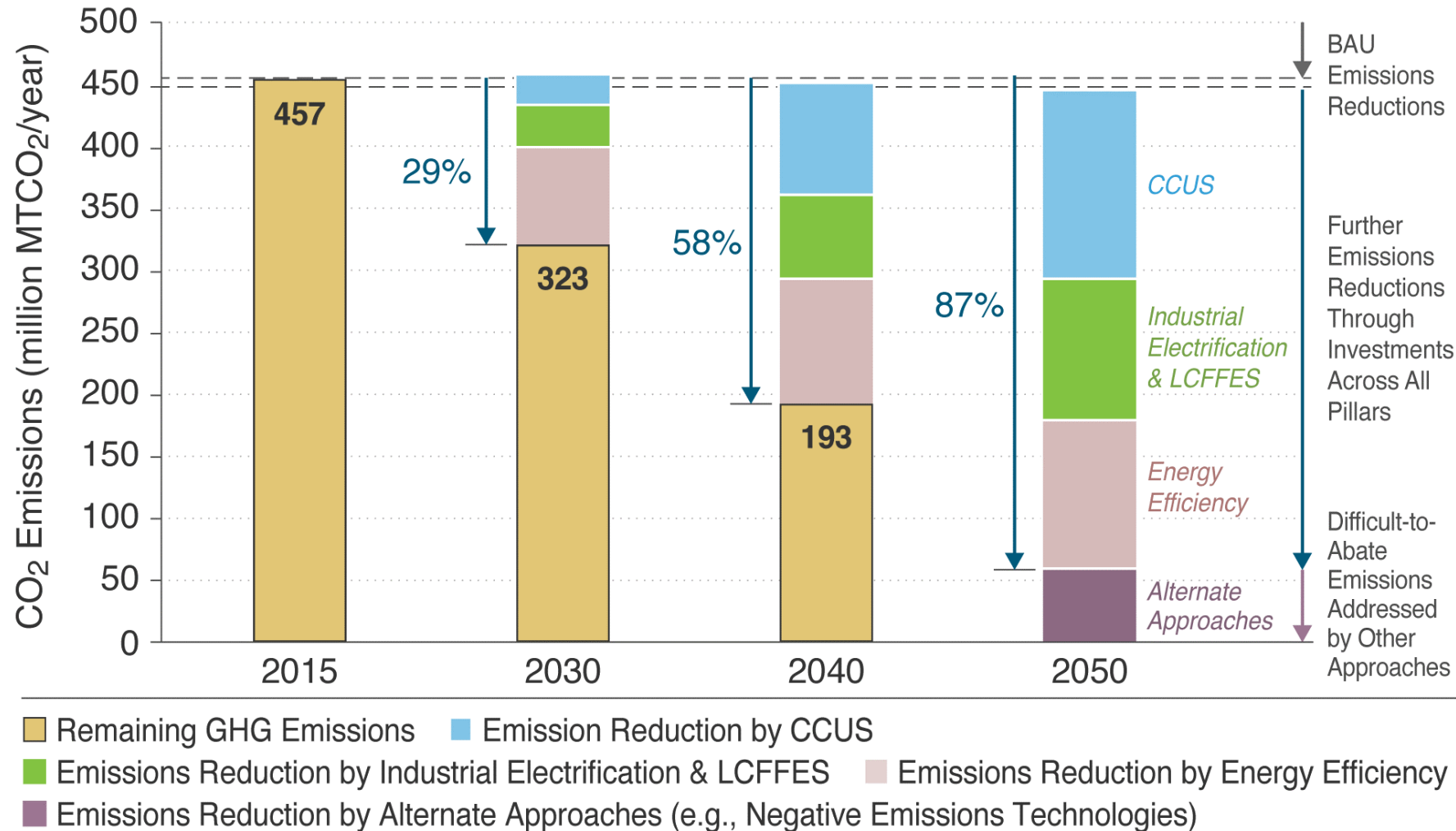


Petroleum Refining



Cement

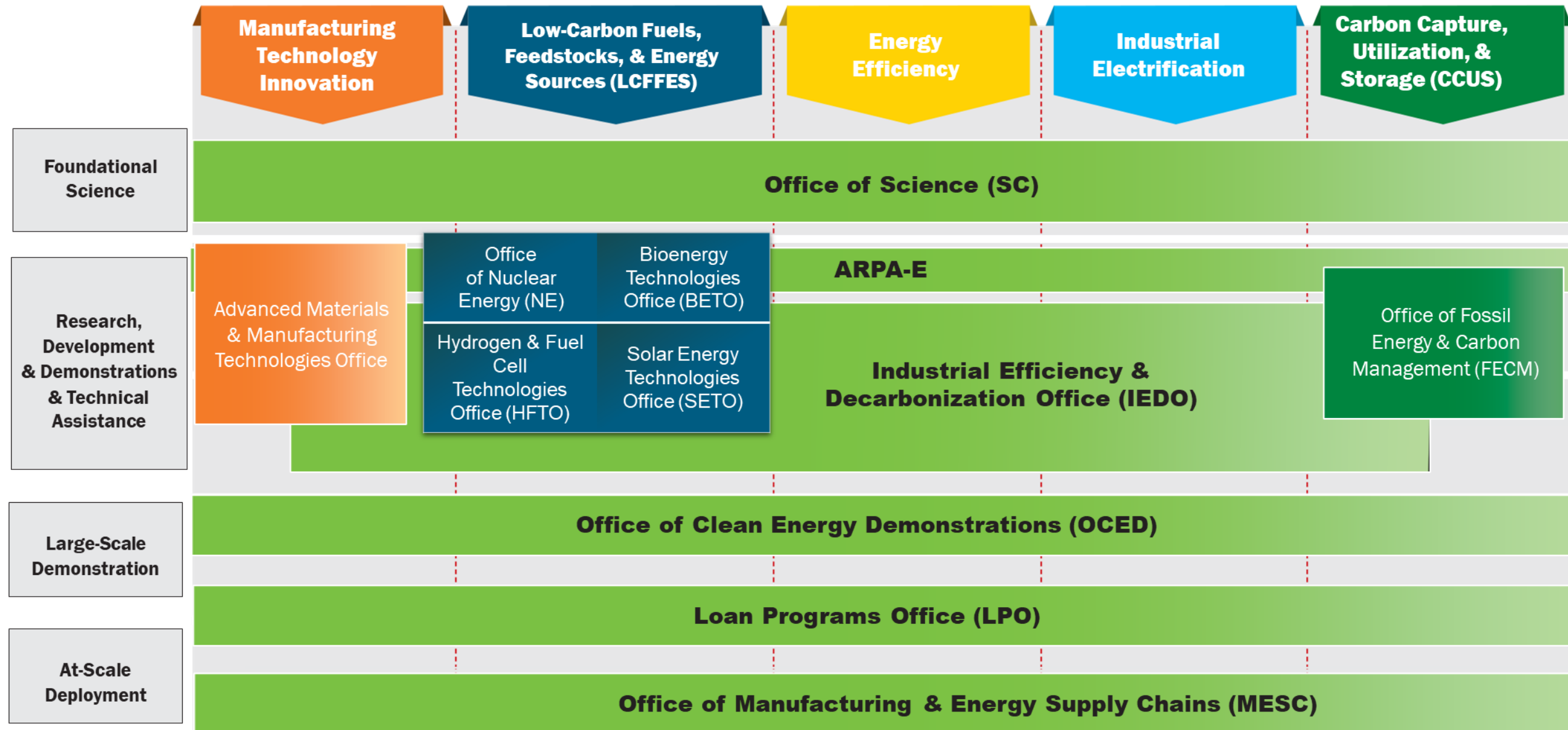
# 2050 Near-Zero Industrial GHG Emissions Scenario



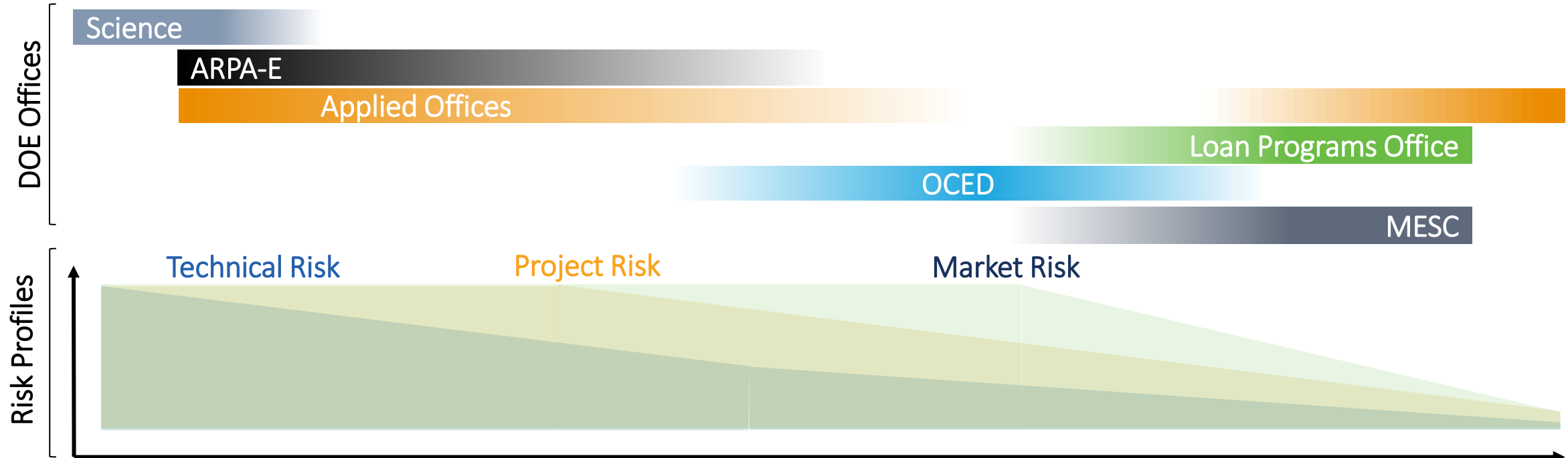
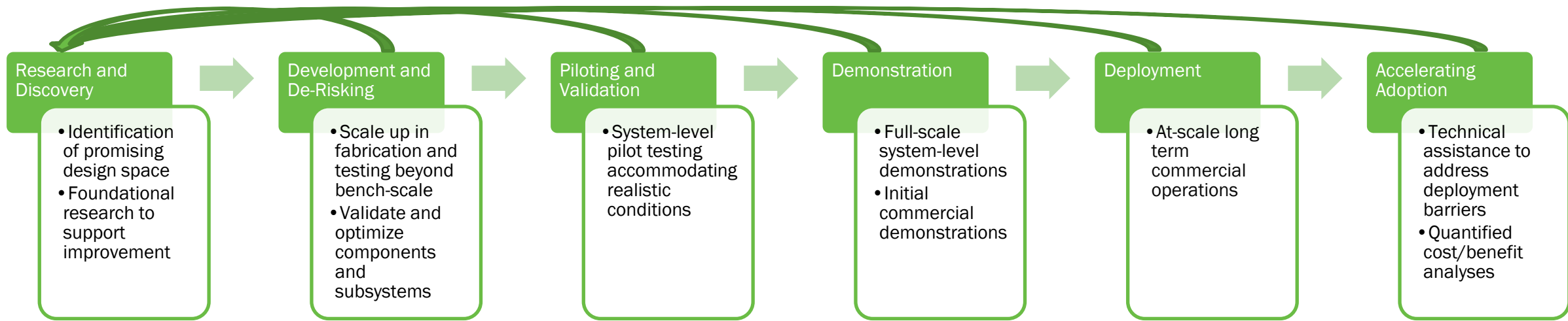
**\*Subsectors included in Roadmap analysis: Iron & Steel, Chemicals, Food & Beverage, Petroleum Refining, and Cement. (Near zero GHG scenario, excluding feedstocks. Source: DOE Industrial Decarbonization Roadmap)**



# DOE Offices Share a Common Strategic Framework



# Role of DOE's Technology Development Programs





### Technology Developer

Small business, NFP, startups, RD&D centers



### Solution Provider

Manufacturers, suppliers, integrator, startups

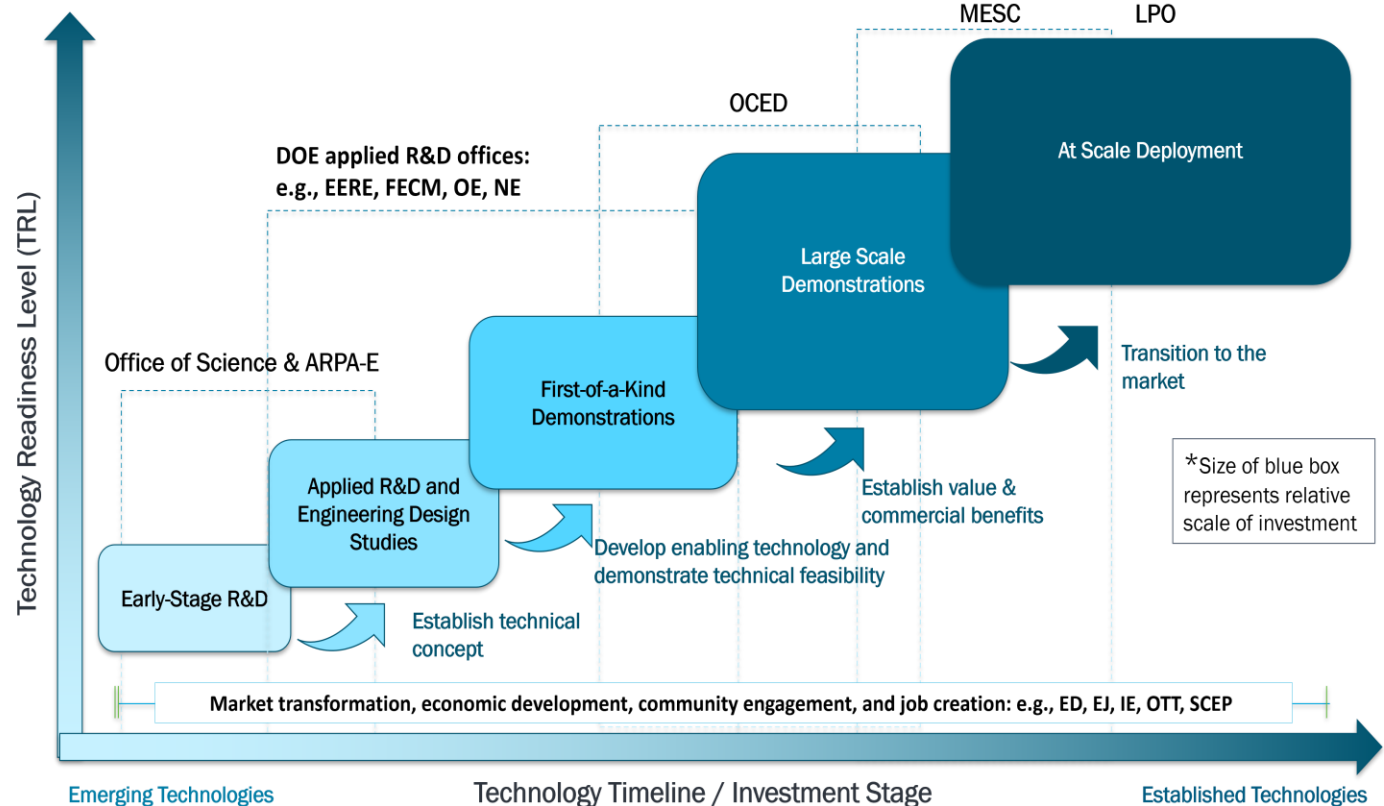


Science and Innovation

Infrastructure


All DOE Offices

Accelerated Adoption



**MESC**  
OFFICE OF MANUFACTURING AND ENERGY SUPPLY CHAINS

# Assessments and Market Opportunities




Sustainable Energy & Environmental Systems Department  
Energy Analysis & Environmental Impacts Division  
Lawrence Berkeley National Laboratory  
LBNL-2001478

## Electrification of U.S. Manufacturing With Industrial Heat Pumps

M. Jibran S. Zuberi<sup>1</sup>, Ali Hasanbeigi<sup>2</sup>, William R. Morrow<sup>1</sup>

<sup>1</sup>Lawrence Berkeley National Laboratory  
<sup>2</sup>Global Efficiency Intelligence




JCI



## Industrial Decarbonization Roadmap

DOE/EE-2635  
September 2022

United States Department of Energy  
Washington, DC 20585



Siemens



## Advanced Manufacturing Office

### Thermal Process Intensification: Transforming the Way Industry Uses Thermal Process Energy


May 2022



Industrial Technologies Program  
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

## A Best Practices Steam Technical Brief

### Industrial Heat Pumps for Steam and Fuel Savings



U.S. Department of Energy  
Energy Efficiency and Renewable Energy  
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

ORNL/TM-2021/2150

## Technology Assessment on Low-Temperature Waste Heat Recovery in Industry



OAK RIDGE NATIONAL LABORATORY  
MANAGED BY UT-BATTELLE  
FOR THE U.S. DEPARTMENT OF ENERGY

Arvind Thekdi  
Sachin Nimbalkar  
Senthil Sundaramoorthy  
Kristina Armstrong  
Anthony Taylor  
Jack Gritton  
Thomas Wenning  
Joe Cresko

September 2021

RIDGE NATIONAL LABORATORY  
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

GEA



# BIL and IRA Investments for Industrial Decarbonization

The Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act (IRA) provide billions in RDD&D investments and tax incentives to create an efficient and competitive industrial sector with net-zero greenhouse gas emissions by 2050.

## Bipartisan Infrastructure Law

### **\$6.3 billion in anticipated funding for DOE's Industrial Demonstrations Program**

- DOE will fund projects that focus on the highest emitting and hardest to abate industries where decarbonization technologies can have the greatest impact.

### **\$150 Million Expansion of Industrial Assessment Centers (IACs) & \$400 Million in Program Implementation Grants**

- Expand reach of IACs by providing training to staff and students on new technologies, practices, and tools; expanding workforce development activities – particularly within disadvantaged communities.
- Implementation grants program provides direct financial assistance to reduce or offset the costs of implementing recommendations from assessments for small and medium-sized manufacturers.

## Inflation Reduction Act

### **\$10 Billion 48C Qualifying Advanced Energy Project Tax Credits**

- DOE, Treasury and IRS announced the intent to release \$4 billion in a first round of tax credits for projects that reduce greenhouse gas emissions at industrial facilities.
- Projects must re-equip an industrial or manufacturing facility with equipment designed to reduce greenhouse gas emissions by at least 20 percent through the installation of one of more of the following:
  - Low- or zero-carbon process heat systems.
  - Carbon capture, transport, utilization, and storage systems
  - Energy efficiency and reduction in waste from industrial processes.
  - Any other industrial technology designed to reduce greenhouse gas emissions.

# U.S. Department of Energy Earthshots

<https://www.energy.gov/policy/energy-earthshots-initiative>

**Hydrogen Shot™** – June 7, 2021. Accelerate innovations and spur demand of clean hydrogen by reducing the cost by 80% to \$1 per 1 kilogram in 1 decade.

**Long Duration Storage Shot™** – July 14, 2021. Affordable grid storage for clean power by reducing the cost of grid-scale energy storage by 90% for systems that deliver 10+ hours of duration within the decade.

**Carbon Negative Shot™** – November 5, 2021. Technologies and approaches to remove CO<sub>2</sub> from the atmosphere and durably store it at meaningful scales for less than \$100/net metric ton.

**Enhanced Geothermal Shot™** – September 8, 2022. Dramatically reduce the cost of enhanced geothermal systems by 90%, to \$45 per megawatt hour by 2035.

**Floating Offshore Wind Shot™** – September 15, 2022 with the goal of driving down costs to \$45 per megawatt hour by 2035 to spur U.S. leadership in floating offshore wind technology, accelerate decarbonization, and deliver benefits for coastal communities.

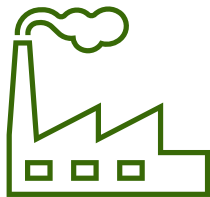
**Industrial Heat Shot™** – September 21, 2022. Develop cost-competitive industrial heat decarbonization technologies with at least 85% lower greenhouse gas emissions by 2035.



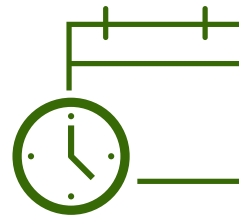


# Industrial Heat Shot

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



> 85% Lower Emissions



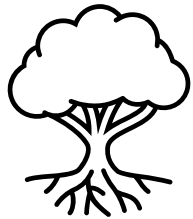
2035

# Industrial Heat is Essential and Pervasive

Every major industry subsector uses heat in different ways to make products...

**drying**

paper,  
batteries



**steam**

pasteurized food



**distillation**

high purity  
chemicals



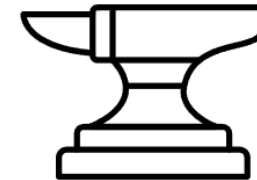
**melting**

formed plastics,  
semiconductors



**smelting**

iron, copper,  
vehicle bodies



**calcining**

cement,  
fuel cell catalysts



~300°C

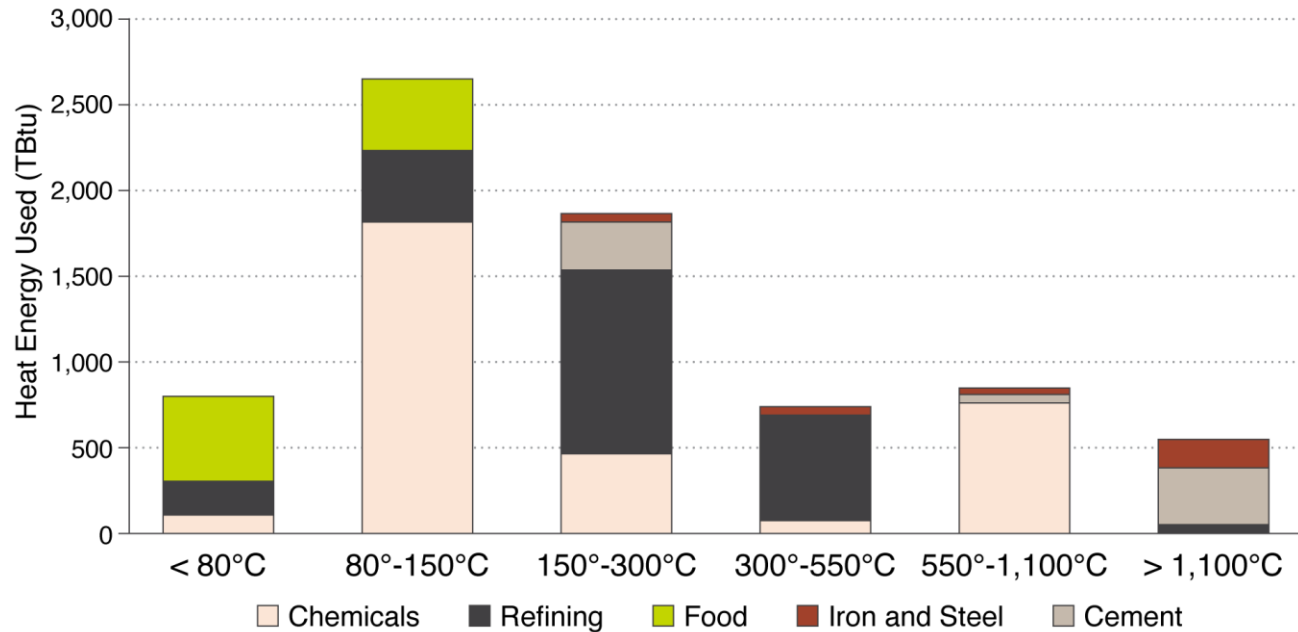
Process Temperatures Needed

>800°C

Emissions equivalent to over half of U.S. home energy use



# Thermal Processes and Systems



Distribution of process heat temperature ranges by industrial subsector in 2014. Data source: McMillan 2019

## Technology Development Priorities

**Electric and hybrid heating systems** to replace fuel burning heaters.

**High-temperature industrial heat pumps** which can efficiently transfer heat from waste-heat streams to useful process heating applications up to 200°C.

**Transformative low thermal budget processes**, which achieve similar end products to current processes while utilizing significantly less thermal energy.

**Membrane technologies** that utilize mechanical and electrical instead of thermal energy for separations in several industries.

# Industrial Heat Shot: Key Characteristics

U.S. manufacturing is **diverse**, with a **heterogenous** array of **processes and operations** that use heat in **multiple ways**.

We need a **portfolio of solutions** that:

- 1** Meet or Exceed Operational Demands
- 2** Are Cost Competitive
- 3** Reach Industrial Scale

# IHP: Key RDD&D Priorities

Technology Area of Interest	Key Opportunities and Barriers	R&D Focus to Realize Opportunities and Overcome Barriers	Title	Status (Planned, Open, etc.)	Description of Relevant Topics/AOIs/etc.
Industrial Heat Pumps (IHP)	<p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>Provide low-temp process heat</li> <li>Waste heat utilization</li> <li>High efficiency (COP &gt; 1)</li> </ul> <p><b>Barriers</b></p> <ul style="list-style-type: none"> <li>OpEx: cost of electricity vs. NG</li> <li>CapEx: custom equipment, integration with existing processes</li> <li>Direct emissions from refrigerants</li> <li>Maximum temp: ~150 C</li> </ul>	<ul style="list-style-type: none"> <li><b>Simplify system design and integration:</b> standardized or modular designs for common applications, standardized components, and approaches for system design and optimization (e.g., advancement of pinch analysis methods; novel machine learning/artificial intelligence-based methods for system design, heat integration, and/or operational strategies)</li> <li><b>Advances for IHP components:</b> low GWP (&lt; 10) refrigerants with high <math>T_{crit}</math> and low <math>P_{crit}</math>; new construction materials that can reduce capital costs; temperature-resistant components; heat exchanger materials and design; compressors for high temp heat pumps (<math>T_{sink}</math> up to 200 C)</li> <li><b>Highly innovative approaches:</b> non-refrigerant-based solutions (e.g., non-vapor compression solutions, functional materials), heat-activated heat pumps, and steam-generating heat pumps</li> <li>Pilot-scale demos with energy and techno-economic assessments to enable IHP implementation</li> </ul>	<a href="#">IEDO FY23 Multi-Topic FOA</a>	Full applications submitted Review in progress	<p>Topic 1: Decarbonizing Industrial Heat</p> <ul style="list-style-type: none"> <li>AOI 3. Industrial Heat Pumps: Design and integration of IHPs (<math>T_{sink} \leq 200</math> C), including: standardized/modular designs for common applications; standardized components; approaches for system design and optimization; next-generation low-GWP (&lt; 10) refrigerants with high <math>T_{crit}</math> and low <math>P_{crit}</math>; new construction materials to reduce capital costs; temperature-resistant components; heat exchanger materials and design; compressors; non-refrigerant-based solutions, heat-activated HPs; and steam-generating HPs</li> </ul>
			<a href="#">FY22 Industrial Efficiency and Decarbonization FOA</a>	Selections announced 6/15/2023	<p>Topic 6: Cross-sector Decarbonization Technologies</p> <ul style="list-style-type: none"> <li>AOI 3. Industrial Heat Pumps: focus on the integration of IHP technology into existing industrial process heating systems, supplying heat at or below 200 C. Targeting advances in heat pump components such as improved heat exchangers, compressors, new materials, refrigerants, and non-refrigerant-based solutions.</li> </ul>
			<a href="#">FY23 SBIR/STTR Phase 1 Release 2</a>	Award Notifications TBA July 2023	<p>Subtopic C56-10d: Industrial Decarbonization</p> <ul style="list-style-type: none"> <li>AOI 2. Industrial Heat Pumps to Enable Electrification: cost-effective IHP system applications that can go up to 200 C with a focus on industrial process heating.</li> </ul> <p>Topic C56-19: Industrial Efficiency and Decarbonization</p> <ul style="list-style-type: none"> <li>Subtopic b. Enhanced Waste Heat Recovery through Highly Efficient Heat Exchangers: non-metallic heat exchangers for industrial heat pumps to maximize heat transfer and system efficiency. Seeking applications that can improve compactness, manufacturing potential, corrosion resistance, and cost.</li> </ul>
			<a href="#">FY22 SBIR/STTR Phase 1 Release 2</a>	Award Notifications announced 5/17/2022	<p>Topic 19: Advanced Manufacturing</p> <ul style="list-style-type: none"> <li>Subtopic a. Decarbonizing Industrial Heat with Heat Pumps – Industrial Heat Pumps Research: focusing on cost-effective IHP applications that go up to 200 C and can be integrated into existing industrial processes via a systems approach.</li> </ul>

# Active IEDO Funding Opportunities

## Clean Energy Manufacturing Innovation Institute for Industrial Decarbonization through Electrification and Process Heating FOA

- Will provide up to \$70 million in federal funding to develop and fund a new Manufacturing USA institute
- Supporting research, development, and demonstration (RD&D) for scaling electrified processes that reduce emissions, improved flexibility, and enhanced energy efficiency of industrial process heating

## Onsite Energy Technical Assistance Partnerships FOA

- \$23 million will fund the establishment of a regional network of TAPs to help industrial facilities and other large energy users increase the adoption of onsite energy technologies
- The TAPs will help facilities providing specialized technical assistance ranging from initial site screenings to more advanced analysis to support project installations

## Decarbonization of Water Resource Recovery Facilities (D-WRRF) FOA

- \$23 million funding opportunity to accelerate RD&D to lower GHG emissions from WRRFs
- Projects will help decarbonize the US water treatment sector, which has full lifecycle GHG emissions on par with the food and beverage sector

## Industrial Efficiency & Decarbonization FOA

- \$104 million funding opportunity advancing decarbonization technologies to reduce the carbon footprint of the industrial sector
- Projects funded under the FOA will drive the transformational technology and innovation necessary to reduce industrial greenhouse gas emissions.



# 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 Funding Opportunity: FY23 Multi-topic FOA

## DOE 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 that will:
  - Advance high impact RD&D projects to reduce GHG emissions across the U.S. industrial sector.
  - Develop the next-gen technologies required to decarbonize industry, revitalize American manufacturing, create good-paying jobs, and improve community health.
  - Focus on cross-sector approaches to industrial decarbonization.
- This funding opportunity is part of the new [Technologies for Industrial Emissions Reduction Development \(TIEReD\) Program](#) for DOE's basic and applied research offices.



Applications review is in progress



# IEDO's Technical Assistance Efforts



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

**PROGRAMS  
INCLUDE:**

**BETTER  
PLANTS**

**ONSITE ENERGY  
PROGRAM**

**50001 READY  
& SEP 50001**

**Workforce  
Development**

# Why Companies Join Better Plants

## Recognition

### Developing Innovative, Replicable Solutions with Market Leaders

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



## Technical Assistance

### Making Energy Efficient Investments Easier

- Software tools for Energy Management
- Financing Navigator
- Diagnostic Equipment Program
- Technical Publications

## Access to Innovation

### Innovation to Drive Savings

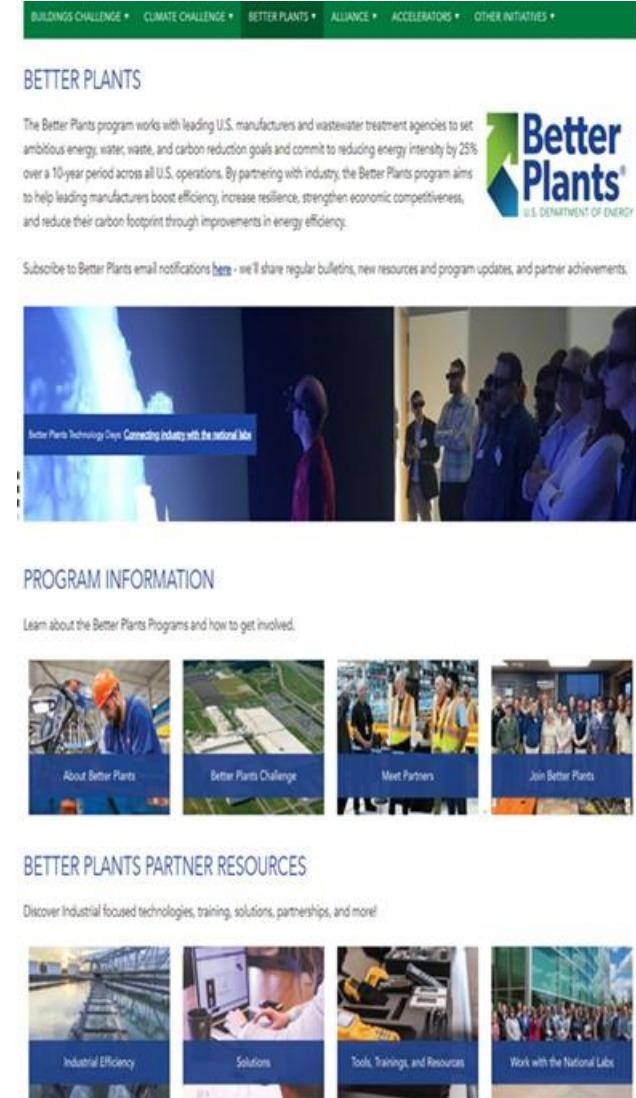
- DOE National Lab Visits
- Industrial Technology Validation

## Workforce Development

### Helping You Meet Your Challenges of Today, and Tomorrow

- In-Plant Trainings
- Virtual trainings and bootcamps

<https://betterbuildingsolutioncenter.energy.gov/better-plants>





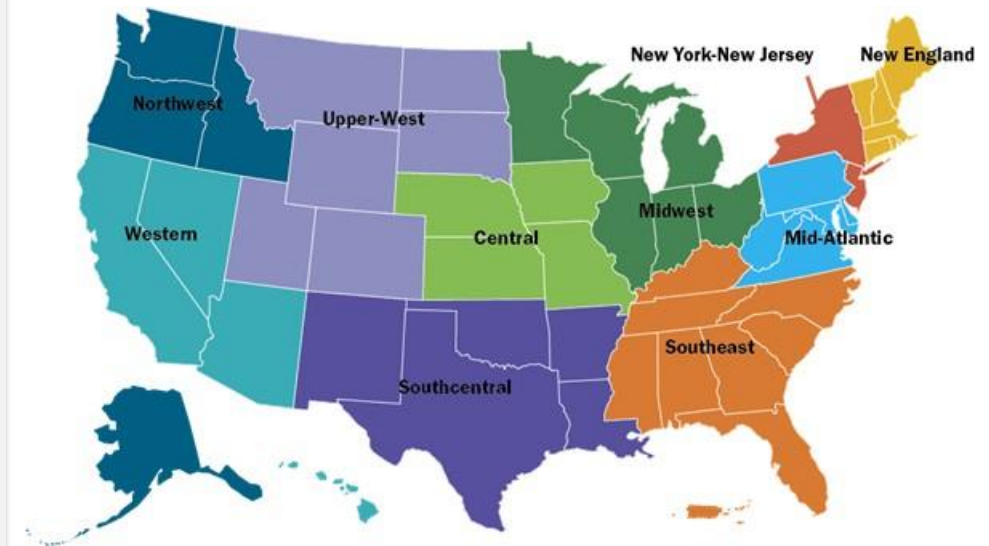
# IEDO Onsite Energy Deployment

The Onsite Energy Deployment program is a new initiative to establish a regional network of technical assistance partnerships to help 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:**

- Identify cost-effective technologies for achieving decarbonization targets and resilience requirements
- Highlight pathways for accelerating the integration of onsite clean energy technologies
- Engage with stakeholders, including utilities and policymakers to identify and reduce barriers to deployment of onsite energy
- Reduce greenhouse gas emissions in the industrial sector while prioritizing energy justice and workforce development



# Defense Production Act (DPA) Heat Pumps (IRA 40555)

- In June 2022, Pres. Biden invoked DPA §303 to provide **DOE with DPA Authority to invest in American manufacturing in five technologies**:
  - Transformers and electric grid components
  - Platinum group metals, electrolyzers, and fuel cells for clean hydrogen
  - Solar components
  - Insulation
  - **Heat pumps—the only technology currently appropriated: - \$250M via IRA**
- **DOE released two RFIs**, one for [heat pump](#) and another for the other [four DPA technologies](#); DOE's [summary of responses](#) was published in March 2023.
- Where other IRA and BIL investments are expected to super-charge demand in retrofit and new markets, **\$250M IRA DPA investment is expected to help accelerate manufacturing** by retooling/expanding production lines and bolstering manufacturing workforce to ensure **domestic capacity at speed and scale** to meet demand.

*DPA Title III – Expediting production and deliveries or services: “To reduce current or projected shortfalls of industrial resources, critical technology items, or essential materials needed for national defense purposes”*



*DPA Heat Pumps FOA is currently open and closes Aug 1.*



# 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)

## 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

### 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%

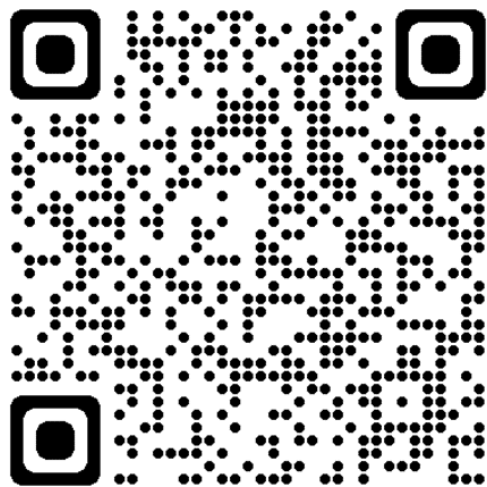




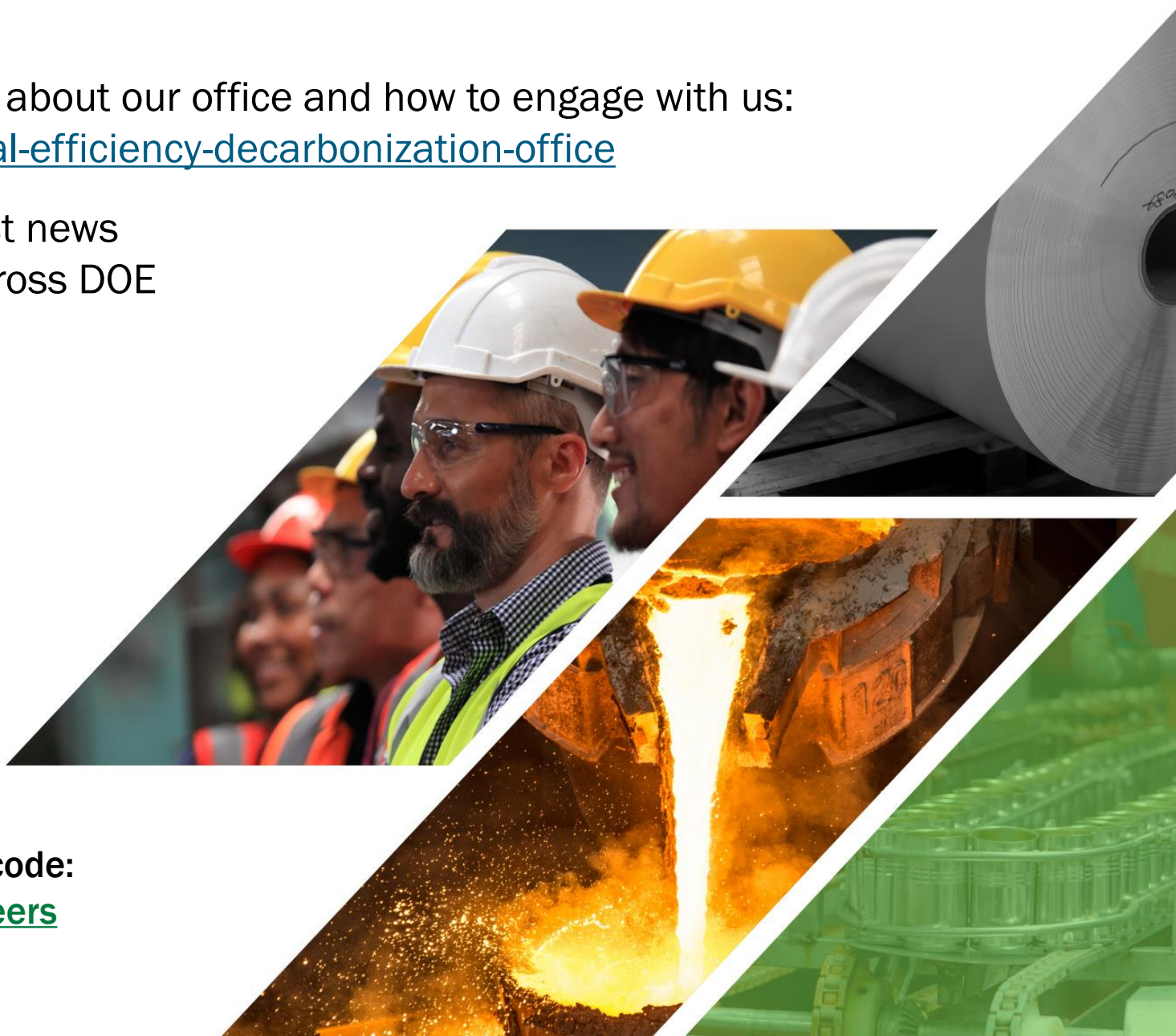
# Engage with IEDO

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<https://www.energy.gov/eere/iedo/industrial-efficiency-decarbonization-office>

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# Questions? Comments? Concerns? Suggestions?

