Challenges, Priorities and Opportunities for Industrial Heat Pumping Technologies

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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

- 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
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

- **Foundational Science**
  - Research, Development & Demonstrations & Technical Assistance
  - Large-Scale Demonstration
  - At-Scale Deployment

- **Office of Energy Efficiency & Decarbonization Office (IEDO)**
  - ARPA-E
  - Office of Science (SC)
  - Office of Clean Energy Demonstrations (OCED)
  - Loan Programs Office (LPO)
  - Office of Manufacturing & Energy Supply Chains (MESC)
  - Carbon Capture, Utilization, & Storage (CCUS)
  - Manufacturing Technology Innovation
  - Low-Carbon Fuels, Feedstocks, & Energy Sources (LCFFES)
  - Energy Efficiency
  - Industrial Electrification
  - Advanced Materials & Manufacturing Technologies Office
  - Office of Nuclear Energy (NE)
  - Bioenergy Technologies Office (BETO)
  - Hydrogen & Fuel Cell Technologies Office (HFTO)
  - Solar Energy Technologies Office (SETO)

U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
Role of DOE’s Technology Development Programs

Research and Discovery
- Identification of promising design space
- Foundational research to support improvement

Development and De-Risking
- Scale up in fabrication and testing beyond bench-scale
- Validate and optimize components and subsystems

Piloting and Validation
- System-level pilot testing accommodating realistic conditions

Demonstration
- Full-scale system-level demonstrations
- Initial commercial demonstrations

Deployment
- At-scale long term commercial operations

Accelerating Adoption
- Technical assistance to address deployment barriers
- Quantified cost/benefit analyses

Risk Profiles
- Technical Risk
- Project Risk
- Market Risk

DOE Offices
- Science
- ARPA-E
- Applied Offices
- Loan Programs Office
- OCED
- MESC

U.S. DEPARTMENT OF ENERGY OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
Technology Developer
Small business, NFP, startups, RD&D centers

Solution Provider
Manufacturers, suppliers, integrator, startups
Assessments and Market Opportunities

Electrification of U.S. Manufacturing With Industrial Heat Pumps

DOE/EE-2635
September 2022

Industrial Decarbonization Roadmap

United States Department of Energy
Washington, DC 20585
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$_2$ 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.
Develop cost competitive industrial heat decarbonization technologies with at least 85% lower greenhouse gas emissions by 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

Process Temperatures Needed

~300ºC

>800ºC

Emissions equivalent to over half of U.S. home energy use
Thermal Processes and Systems

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.

Distribution of process heat temperature ranges by industrial subsector in 2014. Data source: McMillan 2019
Industrial Heat Shot: Key Characteristics

U.S. manufacturing is diverse, with a heterogeneous 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

<table>
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<tr>
<th>Technology Area of Interest</th>
<th>Key Opportunities and Barriers</th>
<th>R&amp;D Focus to Realize Opportunities and Overcome Barriers</th>
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<tr>
<td>Industrial Heat Pumps (IHP)</td>
<td><strong>Opportunities</strong>&lt;br&gt;• Provide low-temp process heat&lt;br&gt;• Waste heat utilization&lt;br&gt;• High efficiency (COP &gt; 1)&lt;br&gt;<strong>Barriers</strong>&lt;br&gt;• OpEx: cost of electricity vs. NG&lt;br&gt;• CapEx: custom equipment, integration with existing processes&lt;br&gt;• Direct emissions from refrigerants&lt;br&gt;• Maximum temp: ~150 C</td>
<td><strong>Simplify system design and integration:</strong> 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)&lt;br&gt;<strong>Advances for IHP components:</strong> low GWP (&lt; 10) refrigerants with high $T_{Crit}$ and low $P_{Crit}$; new construction materials that can reduce capital costs; temperature-resistant components; heat exchanger materials and design; compressors for high temp heat pumps ($T_{Sink}$ up to 200 C)&lt;br&gt;<strong>Highly innovative approaches:</strong> non-refrigerant-based solutions (e.g., non-vapor compression solutions, functional materials), heat-activated heat pumps, and steam-generating heat pumps&lt;br&gt;<strong>Pilot-scale demos with energy and technoeconomic assessments to enable IHP implementation</strong></td>
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<tr>
<th>Title</th>
<th>Status (Planned, Open, etc.)</th>
<th>Description of Relevant Topics/AOIs/etc.</th>
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<tr>
<td>IEDO FY23 Multi-Topic FOA</td>
<td>Full applications submitted, Review in progress</td>
<td>Topic 1: Decarbonizing Industrial Heat  <em>AOI 3. Industrial Heat Pumps: Design and integration of IHPs ($T_{Sink}$ ≤ 200 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 $T_{Crit}$ and low $P_{Crit}$; 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</em></td>
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<td>FY22 Industrial Efficiency and Decarbonization FOA</td>
<td>Selections announced 6/15/2023</td>
<td>Topic 6: Cross-sector Decarbonization Technologies  <em>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.</em></td>
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<td>FY23 SBIR/STTR Phase 1 Release 2</td>
<td>Award Notifications TBA July 2023</td>
<td>Subtopic C56-10d: Industrial Decarbonization  <em>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.</em>  <strong>Topic C56-19: Industrial Efficiency and Decarbonization</strong>  <em>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.</em></td>
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<tr>
<td>FY22 SBIR/STTR Phase 1 Release 2</td>
<td>Award Notifications announced 5/17/2022</td>
<td>Topic 19: Advanced Manufacturing  <em>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.</em></td>
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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

**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

**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

**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 (EPIXC) Institute is DOE’s 7th Clean Energy Manufacturing Innovation Institute.

• EPIXC 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.
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://betterbuildingssolutioncenter.energy.gov/better-plants
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
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 Heat Pumps FOA is currently open and closes Aug 1.

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”
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
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

- Orange: Scope defined by ARRA in 2009
- Blue: 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

Visit the IEDO website for more information about our office and how to engage with us:
https://www.energy.gov/eere/iedo/industrial-efficiency-decarbonization-office

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