U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

IEDO Cross-Sector Technologies (CST) Subprogram Overview

Keith Jamison, Technology Manager

Industrial Efficiency and Decarbonization Office (IEDO)

U.S. DOE IEDO Food and Beverage Industry Workshop

August 31, 2023

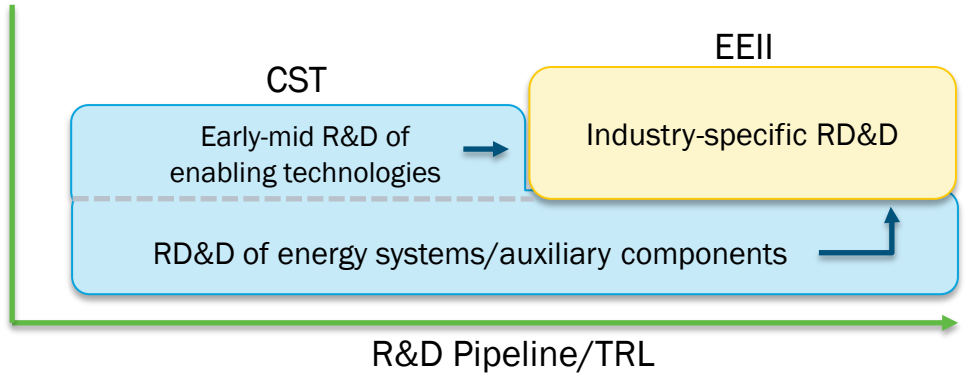
Cross-Sector Technologies within IEDO RD&D

Accelerates the readiness of component and equipment technologies with decarbonization impact across multiple industries.

- Prioritize equipment that can be integrated with existing processes.

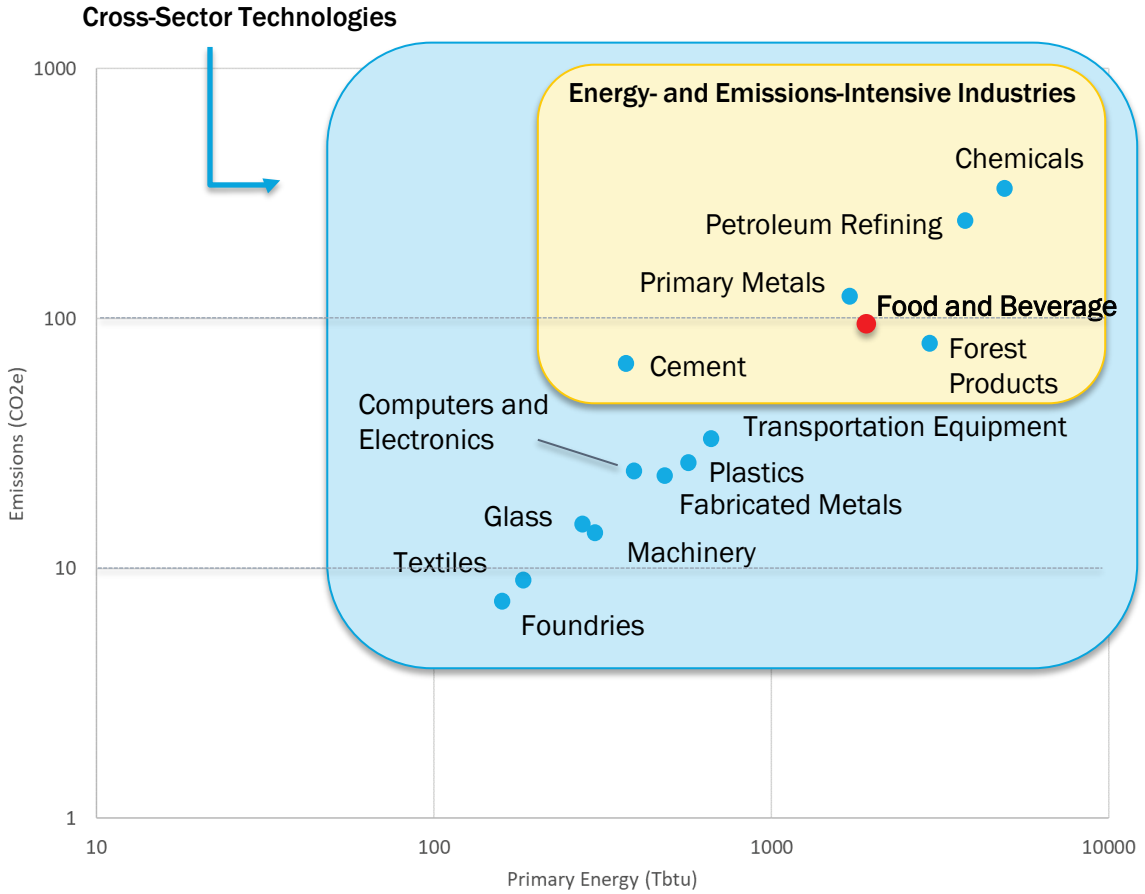
  Enabling technologies developed under CST (mid-TRL) that present integration challenges in industry-specific applications can be further advanced under EEII.

- Advance energy systems and auxiliary components, e.g., waste heat recovery, sensors and controls, thermal energy storage (CST only).
- Develop emerging, next-generation production technologies.



A significant number of energy and emissions reduction challenges are common across all industrial subsectors.

IEDO RD&D Landscape



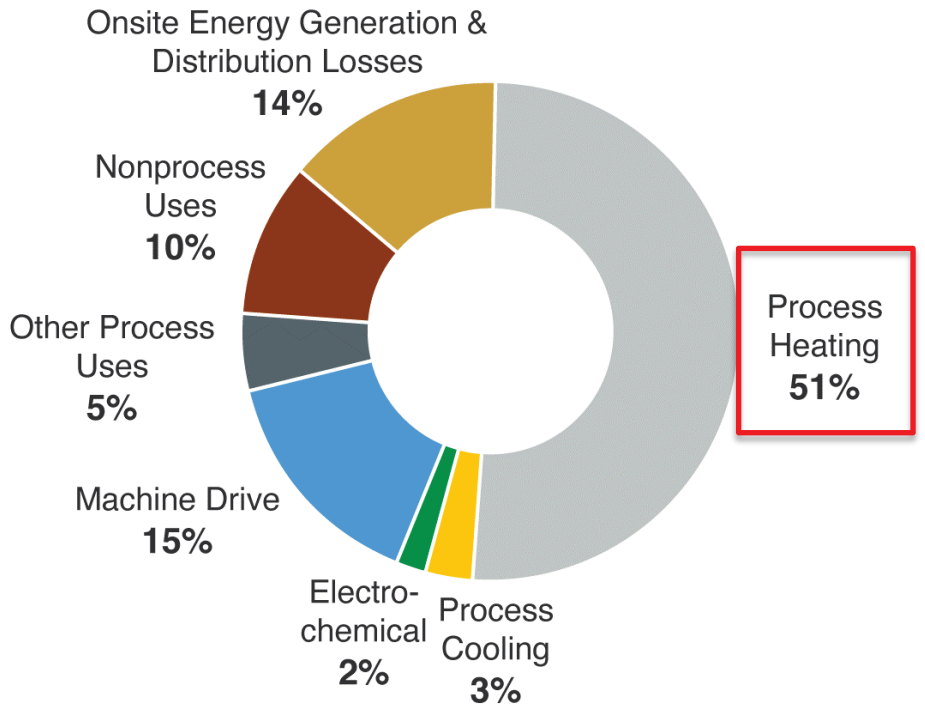
Manufacturing Energy and Carbon Footprints, DOE AMO, 2022.

Key Opportunities for Cross-sector Decarbonization

Process heating

- Largest opportunity for cross-sector impact.
- Accounts for 51% of manufacturing energy use, >90% of this energy is from fossil-fuels.[1]
- Technologies that reduce heating requirements or convert to electric heating are critical to decarbonization.

Breakdown of Energy Use Onsite at Manufacturing Facilities, 2018[2]



[1]Decarbonization Roadmap
[2]Manufacturing Energy and Carbon Footprint, 2018

Key Opportunities for Cross-sector Decarbonization

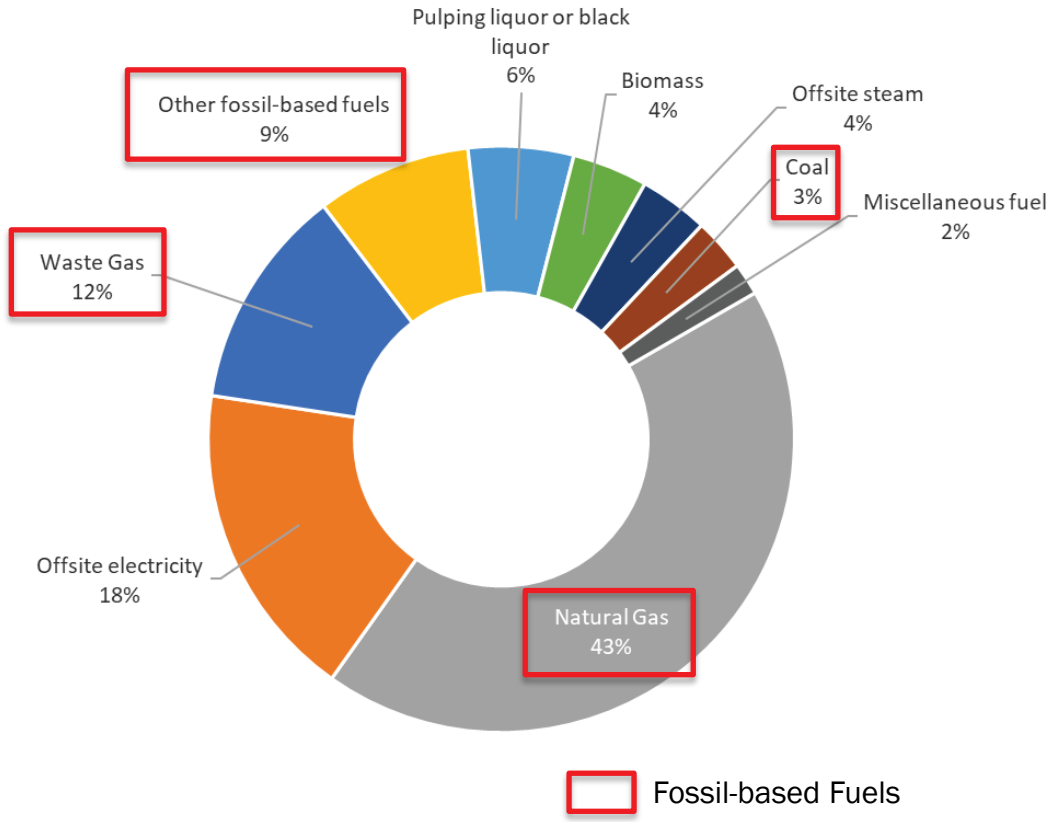
Process heating

- Largest opportunity for cross-sector impact.
- Accounts for 51% of manufacturing energy use, >90% of this energy is from fossil-fuels.[1]
- Technologies that reduce heating requirements or convert to electric heating are critical to decarbonization.

Low carbon fuels, feedstocks, and energy sources

- Displace the need for all fossil energy end uses—particularly process heating, onsite generation, and machine drives.
- Bio-derived fuels, waste/byproducts, energy storage systems, and H_2 use can reduce fossil fuel and offsite electricity demand.

Breakdown of Energy Sources at Manufacturing Facilities, 2018[2]



[1]Decarbonization Roadmap
[2]Manufacturing Energy and Carbon Footprint, 2018

Key Opportunities for Cross-sector Decarbonization

Process heating

- Largest opportunity for cross-sector impact.
- Accounts for 51% of manufacturing energy use, >90% of this energy is from fossil-fuels.[1]
- Technologies that reduce heating requirements or convert to electric heating are critical to decarbonization.

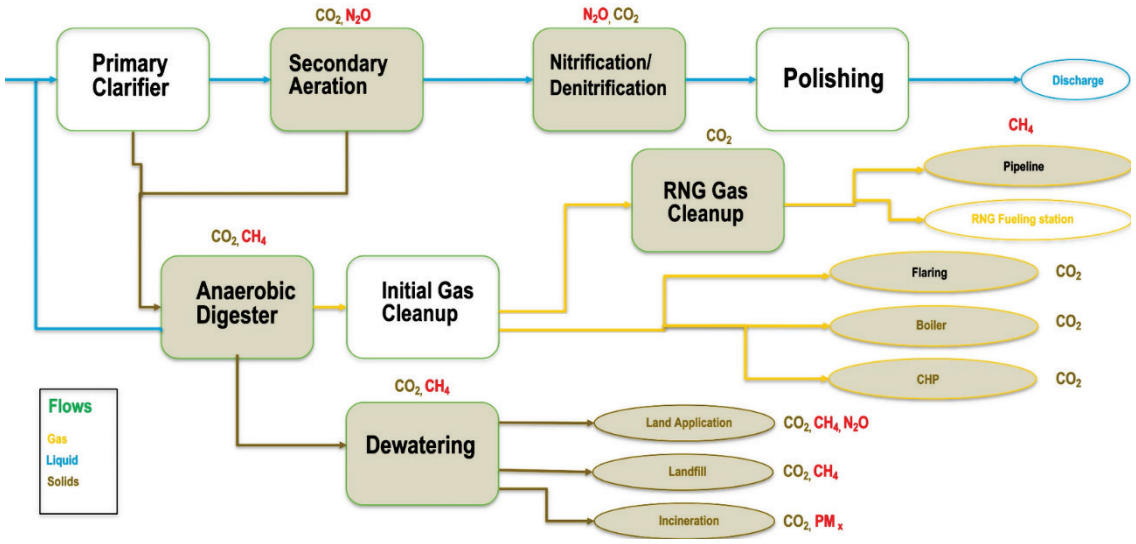
Low carbon fuels, feedstocks, and energy sources

- Displace the need for all fossil energy end uses—particularly process heating, onsite generation, and machine drives.
- Bio-derived fuels, waste/byproducts, energy storage systems, and H_2 use can reduce fossil fuel and offsite electricity demand.

Water and wastewater treatment

- Nearly all industrial operations consume water and produce wastewater.
- Wastewater treatment from municipal, industrial, and agricultural sources is a major source of energy-related and other GHG emissions (CH_4 and NOx). These emissions are tracked separately from manufacturing emissions.

Block Flow Diagram of Wastewater Treatment Process



Sources of emissions shown in brown colored boxes

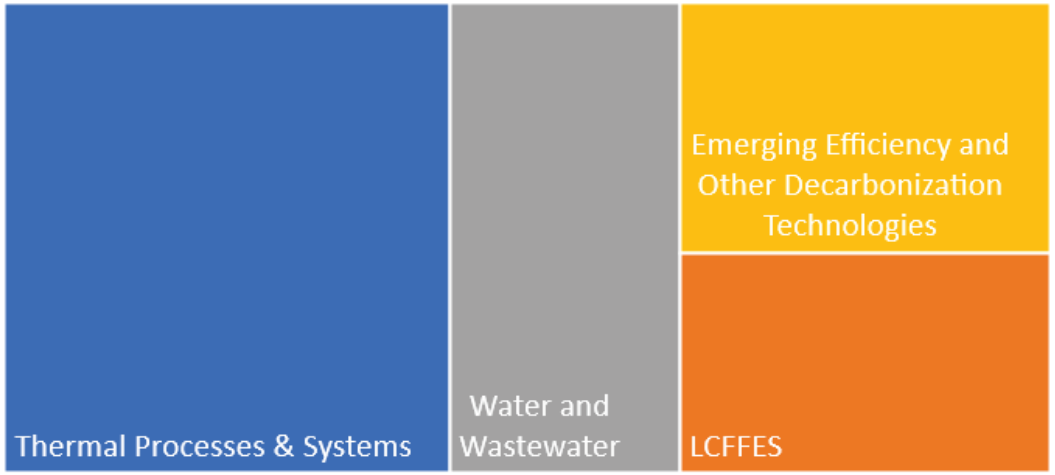
CST Program Priorities and Budget Structure

Industrial Decarbonization is a decades-long journey.

- DOE-wide initiatives, inter-office working groups, analysis, and stakeholder technical workshops will continue to refine and inform future priorities.

Key Activity and FY23 Priorities
Thermal Processes and Systems • Electrification • Innovative low- and no-heat processes
Low Carbon Fuels, Feedstocks, and Energy Sources (LCFFES) • Enable use of low carbon fuels and feedstocks, including H_2, bio-derived fuels. • Flexible CHP
Emerging Efficiency and Other Decarbonization Technologies • Flexible industrial energy use • Thermal energy storage
Energy & Emissions Reductions from Water and Wastewater Treatment • Decarbonization of water resource recovery facilities

CST Budget Breakdown*
FY23 Budget: $90.5M



*Relative size of investment

Decarbonization of Thermal Processes & Systems at IEDO

Reduce the amount of heat used and the emissions from generating heat to make cleaner products by…

Overcoming Critical Barriers

- Develop diverse technology portfolio to address industry's heterogeneous heat demands
- Meet or exceed operational demands
- Address cost competitiveness
- Quantify non-energy/non-emissions benefits
- Scale-up towards commercialization

Advancing Key Technologies

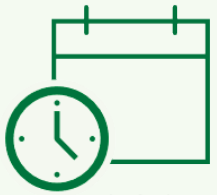
- Electro-technologies & industrial heat pumps
- Innovative low- and no-heat processes & advanced non-thermal separations (e.g., membranes)
- Advanced furnace equipment and process control technologies

Supporting DOE's Industrial Heat Shot

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Industrial Heat Shot

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

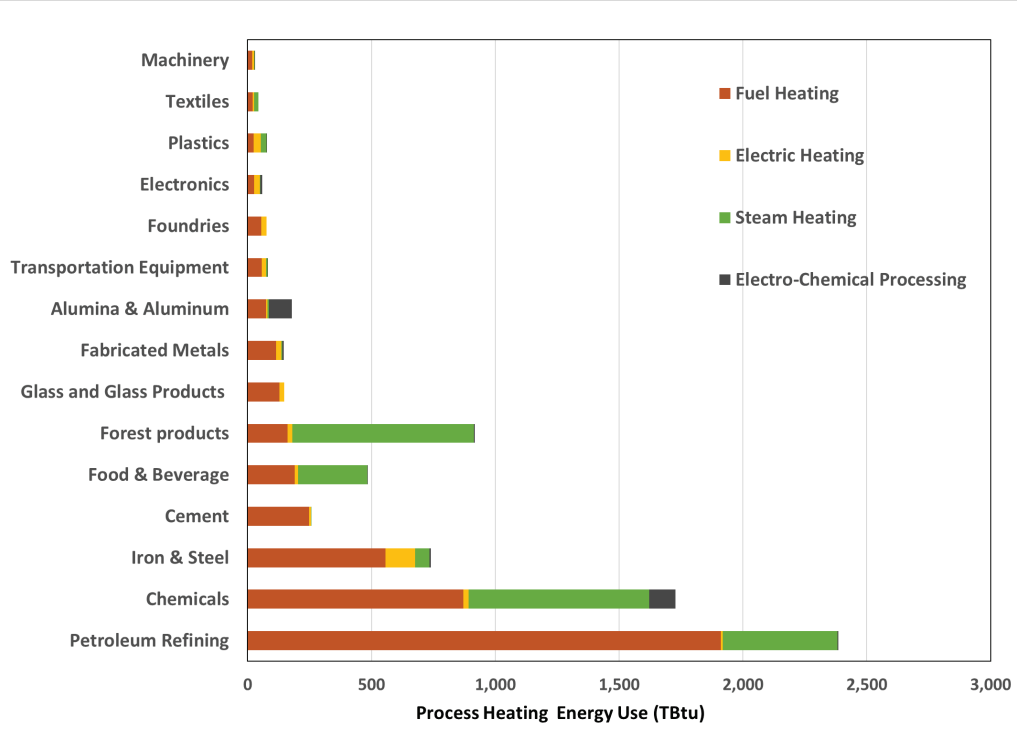
>85% Lower Emissions



2035

Process Heating

- Impacts all manufacturing industries; accounts for >7% of total U.S. energy consumption.
- Drying accounts for an estimated 12-15% of manufacturing process heating energy use; areas with significant drying operations include:
  - Pulp and paper
  - Food and beverage
  - Gypsum
  - Chemicals
  - Textiles



Onsite manufacturing energy end-use facilities in the U.S. in 2018 by end-use.
2018 Manufacturing Energy Consumption Survey (MECS) data.

Thermal Processes & Systems Portfolio

FY19
- **AMO Multi-Topic FOA.** Topic 2: Lower Thermal Budget Processes for Industrial Efficiency & Productivity
  - Subtopic 2.1: *Advances in Industrial and Process Drying* (6 awards; ~$11.7M)
    - Area of Interest 1 – *Novel Drying Systems in Manufacturing*
    - Area of Interest 2 – *Drying Modeling, Sensing, and Control Strategies*

FY20
- **AMO Multi-Topic FOA.** Topic 1: Efficiency Improvements in Advanced Manufacturing Processes
  - Subtopic 1.2: *Enhanced Efficiency of Drying Processes* (3 awards; ~$7.7M)

FY21
- **AMO Multi-Topic FOA.** Topic Area 1: Manufacturing Process Innovation
  - Topic Area 1a: *Efficiency Improvements to Drying Processes* (3 awards; ~$6.2M)

FY22
- **Clean Energy Manufacturing Innovation Institute for Electrification of Process Heating**
  - Selection announcement May 2023 (Arizona State University)
- **Industrial Efficiency and Decarbonization FOA.** Topic Area 6: Cross-sector Decarbonization Technologies
  - Area of Interest 3 – *Industrial Heat Pumps (5 awards; ~$15.9M)*

FY23
- **IEDO Multi-Topic FOA.** Topic Area 1: Decarbonizing Industrial Heat *(applications currently in review)*
  - Area of Interest 1 – *Electrification of Industrial Heat*
  - Area of Interest 2 – *Innovative Low- and No-Heat Processes*
  - Area of Interest 3 – *Industrial Heat Pumps*

Industrial Drying: Active R&D Portfolio

FY19 Awards	Project Title	Technology Approach and Application Focus
Worchester Polytechnic Institute 3 yr project	Novel Energy-Efficient Drying Technologies for Food, Pulp and Paper, and other Energy Intensive Manufacturing Industries	Multiple technologies with primary focus on food and paper products
Molecule Works 3 yr project	A Water Vapor Membrane Separation System for Process Drying and Latent Energy Recovery Membrane	Water vapor membrane for ethanol/water separation
Palo Alto Research Center (PARC) 3 yr project	Filament Extension Atomization for High Solids Loading in Energy Efficient Spray Drying Systems	Spray drying of dairy products

LCFFES Background and High-Level Goals

Low-Carbon Fuels, Feedstocks, and Energy Sources is one of the 4 pillars laid out in the DOE Decarbonization Roadmap for reaching net-zero emissions by 2050.

LCFFES's goal: invest in RD&D that supports adoption and/or use of low-carbon energy sources and feedstocks

Targets:

- Reduce emissions by 85% for clean fuels and energy sources
- Validate process parameters and heating profiles as comparable with incumbent
- Non-GHG emissions reductions comparable to incumbent

Example technical areas of interest:

- Hydrogen and H2-carrier combustion
- Biofuels
- Biomass
- Process byproducts
- Integrating CSP, geothermal, and nuclear into industrial processes

Challenges/Barriers
• Lack of process equipment to address alternative fuel-specific phenomena
• Lack of auxiliary equipment to address industrial infrastructure needs
• Industry hesitation towards adopting new energy sources
• Mitigation of other harmful impacts
• Inadequate supply chain for materials and fuels

LCFFES Portfolio

Current Portfolio

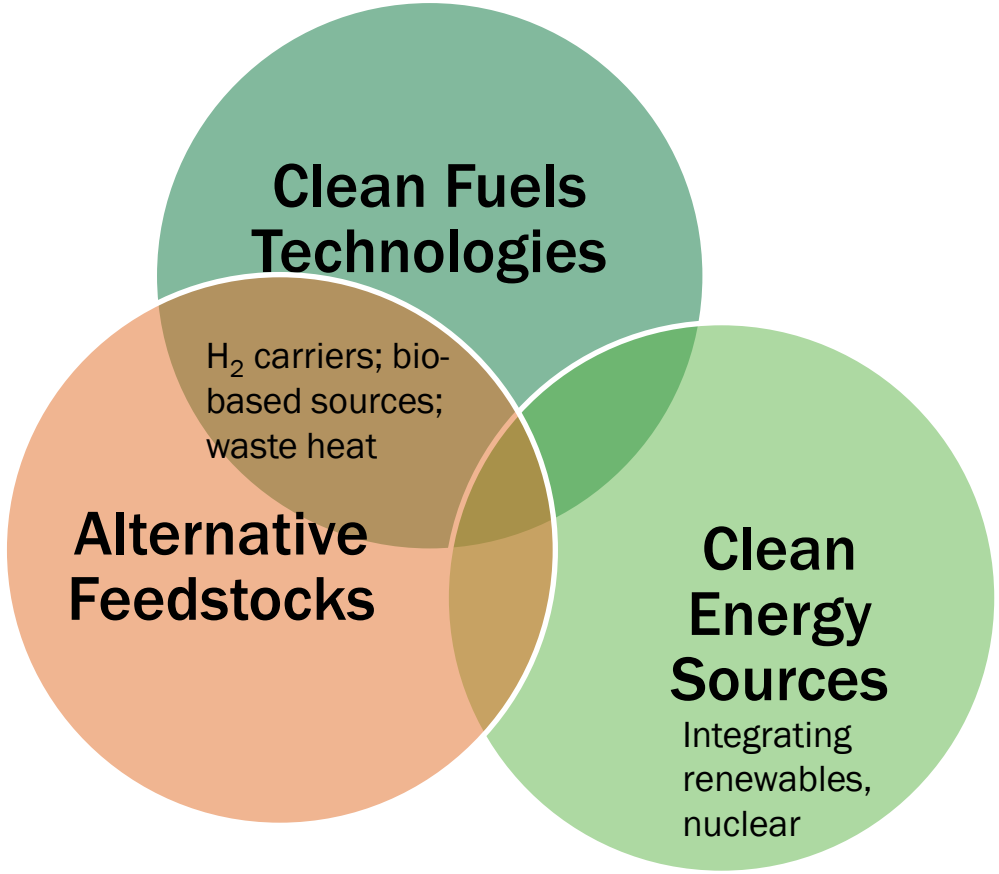
- **Combined Heat and Power (CHP):** CHP efficiency improvements, flexible CHP, high power-to-heat ratio CHP, demonstrations
- **District Energy (DE):** waste heat recovery, validation and verification of renewably powered DE systems

Future Projects

Build upon IEDO's historical program in CHP and DE:

- Waste heat utilization (2 awards from FY22 FOA)
- Low-carbon fuels utilization (FY23 IEDO Multi-Topic FOA, applications in review)
- Low-carbon input CHP for industrial sites (FY23 IEDO Multi-Topic FOA, applications in review)

FY22 and 23 projects



Emerging Technologies Background

Advanced thermal management and operational innovation in 4 key technology areas

Industrial Flexibility

- **Demand flexibility:** develop technologies for grid-interactive industry
- **Energy storage:** develop and integrate thermal energy storage into industrial processes

Outside the Plant

- **Advanced auxiliary equipment:** ultra-high efficiency heat exchangers
- **Waste Heat:** efficient and cost-effective concepts in heat recovery and reuse

- **AI/ML:** train predictive models for next-generation facilities
- **Advanced sensors and controls:** optimize energy productivity in real-time

At the Plant

- **Non-thermal separations:** durable and scalable membranes
- **Other innovative low- and no-heat processes:** electrochemical processes and CO_2 utilization
- **High Performance Computing** to model emerging processes

In the Plant

Address RD&D opportunities through the pillars of decarbonization

Emerging Technologies Portfolio

# Awards	Funding Mechanism	Topic Area	Description
TBD	FY23 MT FOA (applications in review)	• Exploratory Cross-Sector R&D: Flexible Industrial Energy Use & Thermal Energy Storage	• Technologies to enable core unit operations with fixed energy input levels to operate flexibly for flexible industrial energy use. • Develop and integrate thermal energy storage systems for providing process heat.
3	Industrial Efficiency and Decarbonization FOA	• High Operating Temperature Thermal Energy Storage • High Efficiency Waste Heat to Power	• Novel energy transfers for process heating, including waste heat recovery and reuse of process heat. • Enable technologies to demonstrate high operating temperature storage thermal systems to harvest, store, and utilize waste heat.
4	FY22 and FY23 SBIR Phase I	• Enhanced Heat Exchanger Waste Heat Recovery • High Operating Temperature Thermal Storage	• Invest in cost-effective IHP systems integration for industrial process heating. • Focus on high temperature heat exchanger for thermal storage, non-metallic heat exchangers for industrial heat pumps, and thermoelectric heat exchanger systems.

Water-Energy Nexus R&D

Two Major Focal Areas:

- Wet Organic Waste Streams
    - Significant opportunities for direct and indirect emissions reduction
    - Potential to solve pressing community and agricultural waste disposal issues
        - Increases probability of adoption
    - Specific Congressional Direction for Water Resource Recovery Facilities
- “Fit-for-purpose” Water Supplies
    - Meeting the water needs of the future while minimizing energy consumption
    - Diverse array of uses from a variety of non-traditional sources
    - Goal is “Pipe Parity” – competitive with available fresh water sources
        - Future will be increasingly availability constrained in many parts of the country
    - Hub: National Alliance for Water Innovation (NAWI)

Wet Organic Wastes Portfolio

- Research and Development for Advanced Water Resource Recovery Systems
  - 16 projects, total of ~$27M, awarded in FY 21
  - Primary focus on energy efficiency (prior to IEDO/AMMTO split)
    - Subset of projects less than perfectly aligned with IEDO mission
- Decarbonization of Water Resource Recovery Facilities (D-WRRF)
  - 10 projects, total of ~$28M (announced August 2023)
  - Two topics: Unit processes (50% emissions reduction) and Full treatment trains (25% reduction)
  - Selections: https://www.energy.gov/eere/iedo/funding-selections-decarbonization-water-resource-recovery-facilities

Thank you

Keith Jamison, Technology Manager

Industrial Efficiency and Decarbonization Office

IEDO Project Database: https://www.energy.gov/eere/iedo/iedo-project-database