Better Climate CHALLENGE
U.S. DEPARTMENT OF ENERGY

Working Group Report Out

LOW-EMISSION ALTERNATIVES TO INDUSTRIAL THERMAL LOADS

The **Low-Emission Alternatives to Industrial Thermal Loads** Working Group convened more than 20 industrial organizations to discuss how the four key technological pillars of industrial decarbonization can be used to reduce emissions from process heating. The four decarbonization pillars for industry are: 1) Energy efficiency 2) Electrification 3) Low-carbon fuels, feedstocks, and energy sources (LCFFES), and 4) Carbon capture, utilization, and storage (CCUS). This report summarizes the discussions, insights, and outcomes of these sessions, highlighting the innovative technologies, challenges, and strategies for decarbonizing industrial thermal loads.

Through roundtable discussions in each session, partners and DOE technical experts shared obstacles and strategies to adoption, tools and resources, and current company practices to tackle process heating challenges. The working group collected new knowledge on process heating equipment concerns based on the direct experiences of partners. Their input underscored opportunities for modified or adapted implementation methods to advance the commercialization of low-emissions technologies and contribute to broader organizational climate goals.

KEY TAKEAWAYS

The Low-Emission Alternatives to Industrial Thermal Loads Working Group provided key insights, including:

- Energy efficiency and electrification were identified as the technology pillars participants were most interested in exploring to decarbonize process heat
- Common first-step electrification strategies include electrifying hot water and steam generation operations, building HVAC, and fleet vehicles.
- Upgrading existing electrical infrastructure and the availability of reliable renewable electricity are top priorities to maximize the emissions benefit of electrification
- Organizations need clarity on the capital and operating expenditures (CAPEX/OPEX) related to new low-carbon technologies to facilitate their implementation.
- Participants cited boilers, high-temp furnaces, ovens, dryers, and industry-specific thermal processes (e.g., blast furnaces, cupola furnaces, rotary kilns) as the most challenging processes to decarbonize along with glass production and sterilization.
- Though some processes can be decarbonized with currently available technologies, further technological advancements in LCFFES, CCUS, and electrification are needed to address process heating decarbonization completely.

Discussion Topics

Better Climate Challenge partners provided significant input on past experiences, challenges, questions, and organizational goals throughout the seven working group meetings. Participant discussion topics and inputs by pillar included:

- **Energy Efficiency**
    - How energy audits and assessments can be used to identify high-impact decarbonization opportunities
    - Factors to consider when selecting energy-efficient equipment to maximize decarbonization impact and avoid locking in future GHG emissions
    - How energy efficiency can be maintained over time (persistence)
- **Electrification**
    - Advantages and disadvantages when electrifying industrial thermal loads
    - Types of equipment and processes that can be easily or quickly electrified
    - Cost implications of electrification (i.e. installation and maintenance)
- **Low-Carbon Fuels and Feedstocks (LCFFES)**
    - Examples of promising low-carbon alternative fuels that are currently available
    - Technical and operational challenges associated with low-carbon alternative fuels
    - Comparing the cost of low-carbon fuels to conventional fuels
    - Infrastructure requirements when fuel switching
- **Carbon Capture, Utilization, and Storage (CCUS)**
    - Currently existing CCUS technologies that are viable for use with industrial thermal loads
    - Technical and operational challenges associated with CCUS
    - Possible concerns with using CCUS
    - Future work needed to accelerate the development, deployment, and adoption of CCUS technologies

Lessons Learned

One-third of energy consumed for process heating is ultimately lost as waste, and 95% of process heat is currently generated from the burning of fossil fuels. Natural gas, coal, and fuel oil combustion produce criteria air pollutants like nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter (PM) that impact health. There are major areas for potential energy savings and low-emission alternatives to address these issues. These sessions provided valuable insight into new and innovative low-emission alternative technologies, identifying thermal energy-intensive processes, barriers to implementation, and methods to increase the adoption of alternative technologies. sectors learned about and shared valuable perspectives on solar photovoltaic technologies, other renewable energy technologies, battery storage, and thermal energy storage.

During the facilitated discussions, several industry trends and best practices were identified. Some key learnings included which processes the group considered the most challenging to decarbonize, barriers, and factors to consider when decarbonizing. Key learnings are summarized in the table below.

Table: Working Group Lessons Learned by Technology Pillar

Industrial Decarbonization Pillar	Pillar 1: Energy Efficiency	Pillar 2: Electrification	Pillar 3: LCFFES	Pillar 4: CCUS
Adoption Barriers	▶ Higher paybacks due to lower NG prices and lack of financial incentives ▶ Capability to fuel switch in the future	▶ Cost ▶ Regulatory restrictions ▶ Infrastructure limitations (facility and utility)	▶ Reliable, cost-effective supply of low-carbon fuels ▶ Quality infrastructure ▶ Organizational awareness of LCFFES	▶ Cost ▶ Reliability of current carbon capture technology
Operational and Technical Challenges	▶ Impact on production (timing of upgrades, product quality, etc.) ▶ Current and ongoing knowledge of plant personnel ▶ Maintenance and retrofits (i.e. waste heat recovery)	▶ Installation, operating, and maintenance costs ▶ Availability of electrotechnologies at the scale needed ▶ Lead time on utility equipment upgrades	▶ Various risks associated with fuel change (e.g., spatial and temporal availability of solar thermal) ▶ Generating and delivering clean, high-temp heat in smaller confined spaces can be challenging with LCFFES	▶ Familiarity with CCUS in the context of industrial applications ▶ Storage locations near the facility site and pipeline transport safety ▶ Handling amine salts and other byproducts
Priorities for Improvement	Increased technology availability, specifically industrial heat pumps	A cleaner grid with a reduced cost of electricity	Hydrogen-related advancements on a massively accessible scale (i.e. availability via a utility)	Government policy and regulation on costs associated with CCUS

Next Steps

DOE, in collaboration with Oak Ridge National Laboratory, will develop an "Industrial Thermal Loads Decarbonization Scoping Tool" as a resource for facilities to reduce their Scope 1 emissions from process heating and steam systems, structured around the four decarbonization pillars. This scorecard tool will map a facility's decarbonization progress, technology potential within the four pillars, and suggest next steps.