



## Decarbonizing America's Industrial Sector

### Building a Net-Zero Economy Made in America

America's industrial sector is the backbone of the U.S. economy, producing chemicals, electronics, machinery, steel, textiles, and many other products that are critical to our daily lives. It is also key to tackling the climate crisis, as it is currently responsible for approximately one third of domestic greenhouse gas (GHG) emissions. By helping manufacturers and businesses use clean energy, increase efficiency, and integrate new, innovative processes and technologies, the U.S. Department of Energy (DOE) is enabling a cleaner, more competitive industrial sector and moving the nation closer to a net-zero economy that benefits all Americans. These manufacturing improvements will position the U.S. as a leader in the production of clean energy technologies and will also protect public health, reducing the pollutants and toxic materials that disproportionately harm low-income households and communities of color.

### DOE's Industrial Decarbonization Roadmap

The industrial sector is among the most difficult to decarbonize because of the diversity and complexity of energy inputs, processes, and operations. Achieving deep decarbonization of the industrial sector will require focusing both on sector-specific technologies and technologies that can be applied across the industrial sector.

DOE's [2022 Industrial Decarbonization Roadmap](#) identifies four key pillars



driving industrial decarbonization investments:

- 1. Low-Carbon Fuels, Feedstocks, and Energy Sources (LCFFES):** Substituting low- and no-carbon fuel and feedstocks reduces emissions associated with combustion for industrial processes.
- 2. Energy Efficiency:** Energy efficiency is a foundational, crosscutting decarbonization strategy and is the most cost-effective option for emissions reductions in the near term.
- 3. Industrial Electrification:** Leveraging advancements in low-carbon electricity from both grid and onsite renewable generation sources will be critical to decarbonization efforts.
- 4. Carbon Capture, Utilization, and Storage (CCUS):** CCUS refers to the multi-component strategy of capturing generated carbon dioxide (CO<sub>2</sub>) from a point source and using the captured CO<sub>2</sub> to make value-added products or storing it long-term to avoid release.

With input from stakeholders across a diverse range of industries, DOE has identified an additional fifth pillar underpinning industrial decarbonization investments:

- 5. Manufacturing Technology Innovation:** Advancements in manufacturing processes, materials, and technologies are essential to helping manufacturers further optimize their energy use and reduce carbon emissions.

Leveraging this multidimensional approach, DOE launched the [Industrial Heat Energy Earthshot™](#). This initiative sets a bold target to develop cost-competitive solutions for industrial heat with at least 85% lower greenhouse gas emissions by 2035.

### Investments Across the Innovation Pipeline

Some technologies we'll need to fully decarbonize the industrial sector are in early stages of development, while others are much closer to commercialization. DOE is investing in technologies spanning all stages of development and has created closely coordinated initiatives designed to work together to maximize impact across the full innovation pipeline. This work includes large investments in deployment and full-scale demonstration projects through the [Office of Clean Energy Demonstrations' \\$6 billion Industrial Demonstrations Program](#), [Office of Manufacturing and Energy Supply Chains](#), and the [Loan Programs Office](#).

DOE also created the **Technologies for Industrial Emissions Reduction Development (TIERed) Program** to identify and accelerate the development of the full suite of technologies that will be needed by net-zero manufacturers – investing in fundamental science, research, development, and initial pilot-scale demonstrations projects.

DOE offices working in this space include:

- [Office of Energy Efficiency and Renewable Energy](#)
  - [Industrial Efficiency & Decarbonization Office \(IEDO\)](#)
  - [Advanced Materials & Manufacturing Technologies Office \(AMMTO\)](#)
  - [Bioenergy Technologies Office \(BETO\)](#)
  - [Solar Energy Technologies Office \(SETO\)](#)
  - [Hydrogen and Fuel Cell Technologies Office \(HFTO\)](#)
- [Office of Fossil Energy and Carbon Management \(FECM\)](#)
- [Office of Nuclear Energy \(NE\)](#)
- [Advanced Research Projects Agency \(ARPA-E\)](#)
- [Office of Science](#)

## Technologies for Industrial Emissions Reduction Development (TIEReD) Program

DOE's RD&D investments through the Technologies for Industrial Emissions Reduction Development (TIEReD) Program are designed to achieve deep decarbonization across the industrial sector, targeting both industry-specific innovations and crosscutting technologies across the five pillars.

### Low-Carbon Fuels, Feedstocks, and Energy Sources (LCFFES)

#### Clean hydrogen

- Electrolyzer development
- Fossil/waste reforming with CCS
- Photochemical, thermochemical or biological H<sub>2</sub> production
- Hydrogen infrastructure

#### Bioenergy, biofuels, and bio-feedstocks

- Conversion of low-carbon feedstocks to fuels and products
- Coordination across sectors & industries for GHG accounting
- Biomanufacturing for carbon-based products with low net emissions

#### Other low-carbon energy sources

- Further integration of combined heat and power with renewable energy
- Rapid switching for hybrid approaches (e.g., dual gas-electric boilers)
- Low-carbon thermal energy (e.g., nuclear, solar thermal, geothermal)

*The following offices are working on these priorities: Industrial Efficiency and Decarbonization Office, Bioenergy Technologies Office, Advanced Materials and Manufacturing Technologies Office, Solar Energy Technologies Office, Office of Science, Office of Nuclear Energy, Hydrogen Fuel Cells Technologies Office,*

*Office of Fossil Energy and Carbon Management*

### Energy Efficiency

- Improve process efficiency of heating, steam, and motor systems
- Smart manufacturing and advanced data analytics
- Demonstrations of plant automation systems

*The following offices are working on these priorities: Industrial Efficiency and Decarbonization Office, Bioenergy Technologies Office, Advanced Materials and Manufacturing Technologies Office, Office of Science*

### Industrial Electrification

- Scale-up of electrified technologies and development of modular size-matched systems for application needs
- Durability and reliability of electrified services
- Integration with intermittent energy sources (e.g., efficient control systems and interfaces)
- Hybrid and dual-source process heating (e.g., hybrid boilers)

*The following offices are working on these priorities: Industrial Efficiency and Decarbonization Office,*







*Advanced Materials and Manufacturing Technologies Office, Hydrogen Fuel Cells Technology Office, Office of Science*

### Carbon Capture Utilization & Storage (CCUS)

- Improved catalysts and process design to convert CO<sub>2</sub> to chemicals
- System-level techno-economic optimization of integrated carbon capture components, for nominal and specific use cases
- Front-End Engineering Design (FEED) and pre-FEED system-level studies
- Pilot-scale demonstrations for CCUS of emissions from heavy industries
- Continued advancement of other mitigation options, such as direct air capture and forest preservation

*The following offices are working on these priorities: Industrial Efficiency and Decarbonization Office, Office of Science, Office of Fossil Energy and Carbon Management*

### Manufacturing Technology Innovation

- New manufacturing processes to deliver the technologies needed for industrial decarbonization and facility energy management

- Computational optimization of manufacturing processes for efficiency, quality, and repeatability
- Advancements in manufacturing related to critical materials, such as for rare earth magnets needed for efficient motors
- Material design, discovery, and manufacturing for industrial equipment and facility energy management

*The following offices are working on these priorities: Advanced Materials and Manufacturing Technologies Office, Office of Science, Office of Fossil Energy and Carbon Management* ■

### Technical Assistance and Workforce Development

DOE's technical assistance and workforce development initiatives are a key part of the industrial decarbonization approach, ensuring that DOE is addressing the most pressing challenges of today's industrial sector and preparing tomorrow's manufacturing workforce. Key Initiatives include:

- [Better Climate Challenge](#)
- [Better Plants](#)
- [Industrial Assessment Centers](#)
- [Onsite Energy Technical Assistance Partnerships Program](#)
- [50001 Ready](#)



For more information, visit:  
[energy.gov/eere](https://energy.gov/eere)

DOE/EE-2702 • March 2023