U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Overview of DOE Research, Development & Demonstration of Industrial Efficiency and Decarbonization Technologies

Dr. Avi Shultz, Deputy Director, Industrial Efficiency and Decarbonization Office

Industrial Process Emissions Reduction Workshop – San Antonio, TX

March 1, 2023

THE U.S. INDUSTRIAL SECTOR

manufacturing | agriculture | mining | construction

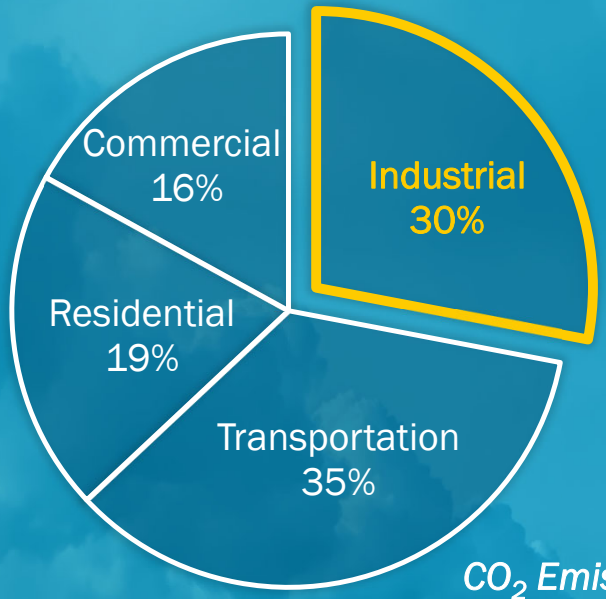
ACCOUNTS FOR

33% of the nation's primary energy use

30% of CO_2 emissions

Anticipated industrial sector energy demand growth of 30% by 2050 may result in a

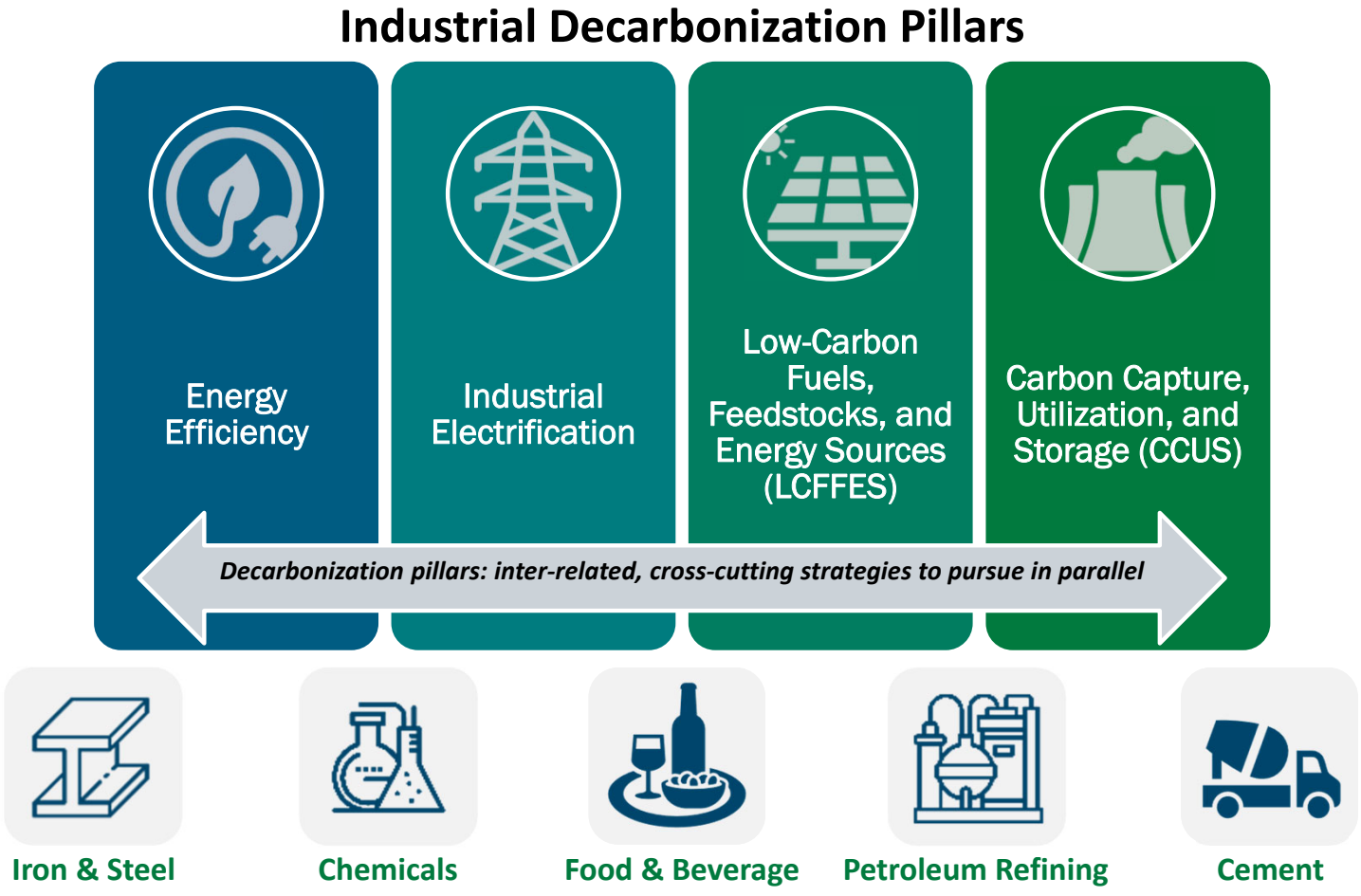
17% CO_2 emissions increase



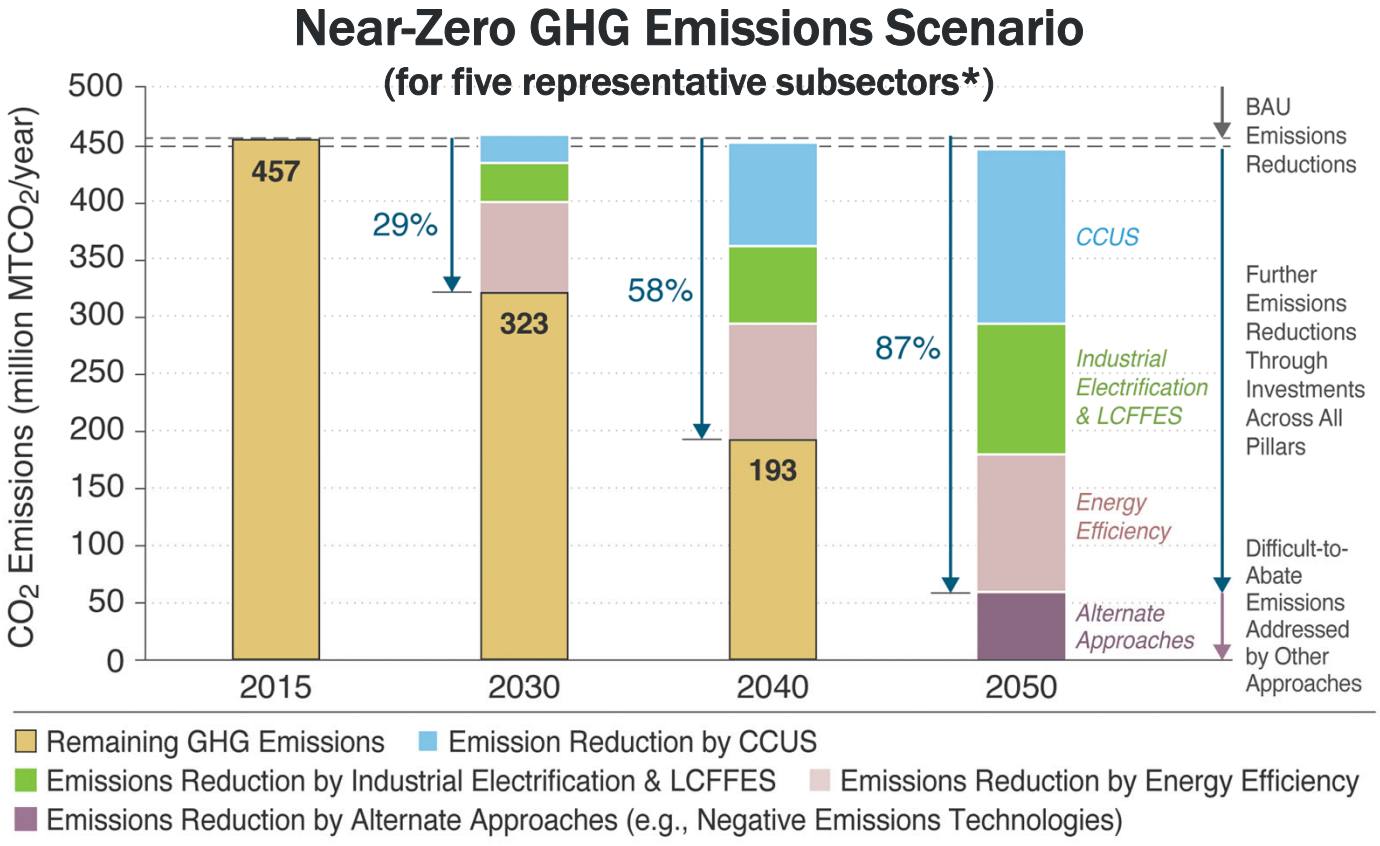
CO_2 Emissions By Sector

EIA, *Annual Energy Outlook 2021 with Projections to 2050.*

DOE Industrial Decarbonization Roadmap



2050 Industrial 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)*

Challenges to Industrial Decarbonization

- The range of facilities, their processes, sources of energy, and end products requires tailored approaches.
- Emissions are the byproducts of chemical reactions or related to processes that require very high heat or fossil fuels as feedstocks.
- Economies of scale and low raw material and energy prices are crucial to profitability and there is little room in budgets for investments in new technology.
- U.S. industrial facilities are facing competition in international markets.
- Technology advances in industrial facilities often require large capital investments and long lead times.

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

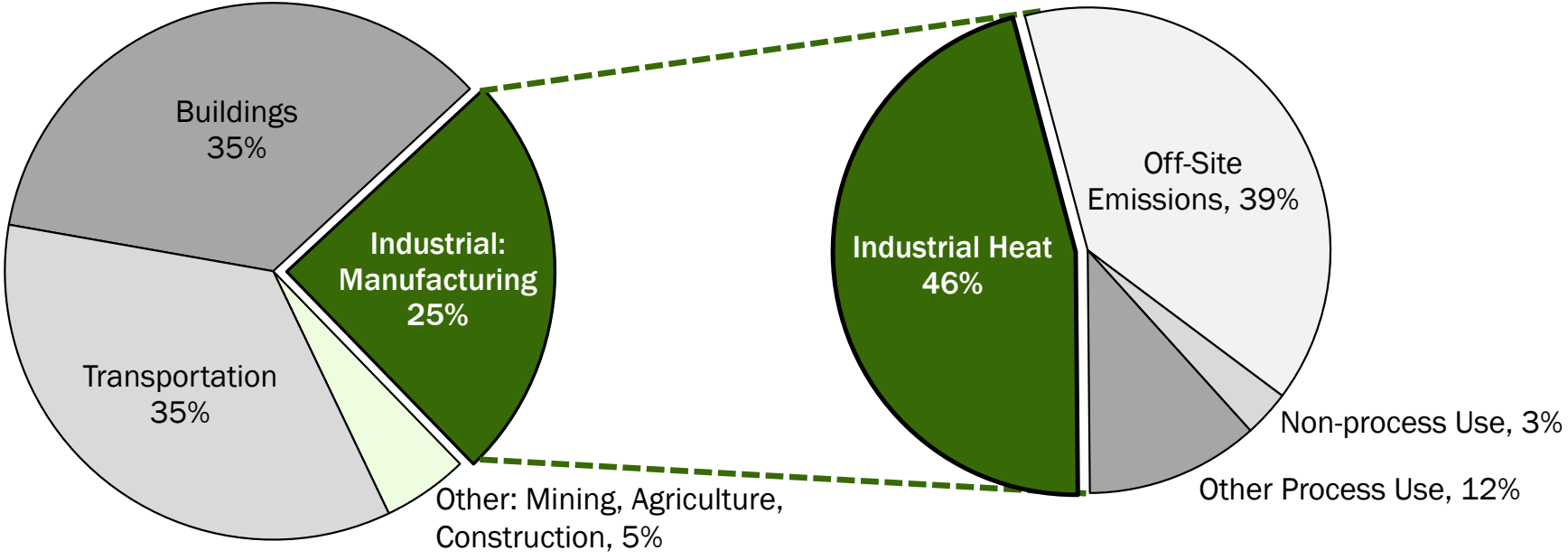
- Implementation grants program provides direct financial assistance to reduce or offset the costs of implementing recommendations from assessments for small and medium-sized manufacturers.

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 a manufacturing facility with equipment designed to reduce emissions by at least 20 percent through one or 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.
  - Other industrial technologies

Industrial Heat Causes 11% of All U.S. Energy-Related Emissions



2020 Energy-Related CO_2 Emissions by U.S. Economic Sector

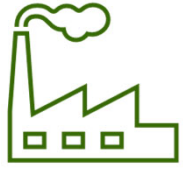
2020 Estimated Industrial: Manufacturing Energy-Related CO_2 Emissions by Source

Sources: EIA Annual Energy Outlook (2021); AMO 2018 Manufacturing Energy and Carbon Footprints (2022)

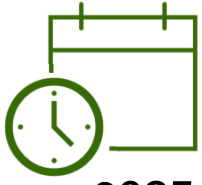
ENERGY earthshots
U.S. DEPARTMENT OF ENERGY

Industrial Heat Shot

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



>85% Lower Emissions



2035

3 Pathways to Decarbonize Industrial Heat

Reduce the amount of heat and/or emissions from heat to make cleaner products

Generate Heat from Clean Electricity

Reduce Emissions:
Electrify equipment & use clean electricity, improve energy efficiency

Examples:
resistive heating, heat pumps, microwave heating, thermal storage, etc.

Integrate Clean Heat from Alternative Sources

Reduce Emissions:
Switch to low-emissions heat sources and increase thermal storage

Examples:
solar thermal, nuclear, geothermal, hydrogen, some sustainable fuels

Innovative Low- or No-Heat Process Technologies

Reduce Emissions:
New chemistry and emerging biotechnology processes to reduce heat demand

Examples:
bio-based manufacturing, electrolysis, ultraviolet curing, advanced separations, etc.

Transition From AMO to Two New Offices

Advanced Manufacturing Office (AMO)

Industrial Efficiency & Decarbonization Office (IEDO)

ENERGY- AND EMISSIONS-INTENSIVE INDUSTRIES

CROSS-SECTOR TECHNOLOGIES

TECHNICAL ASSISTANCE AND WORKFORCE DEVELOPMENT

Advanced Materials & Manufacturing Technologies Office (AMMTO)

NEXT GENERATION MATERIALS & PROCESSES

SECURE AND SUSTAINABLE MATERIALS

ENERGY TECHNOLOGY MANUFACTURING AND WORKFORCE

IEDO Leadership

Dr. Steven McKnight
Acting Director

Dr. Avi Shultz
Deputy Director

Joe Cresko
Chief Engineer

Lauren Hall
Operations Supervisor

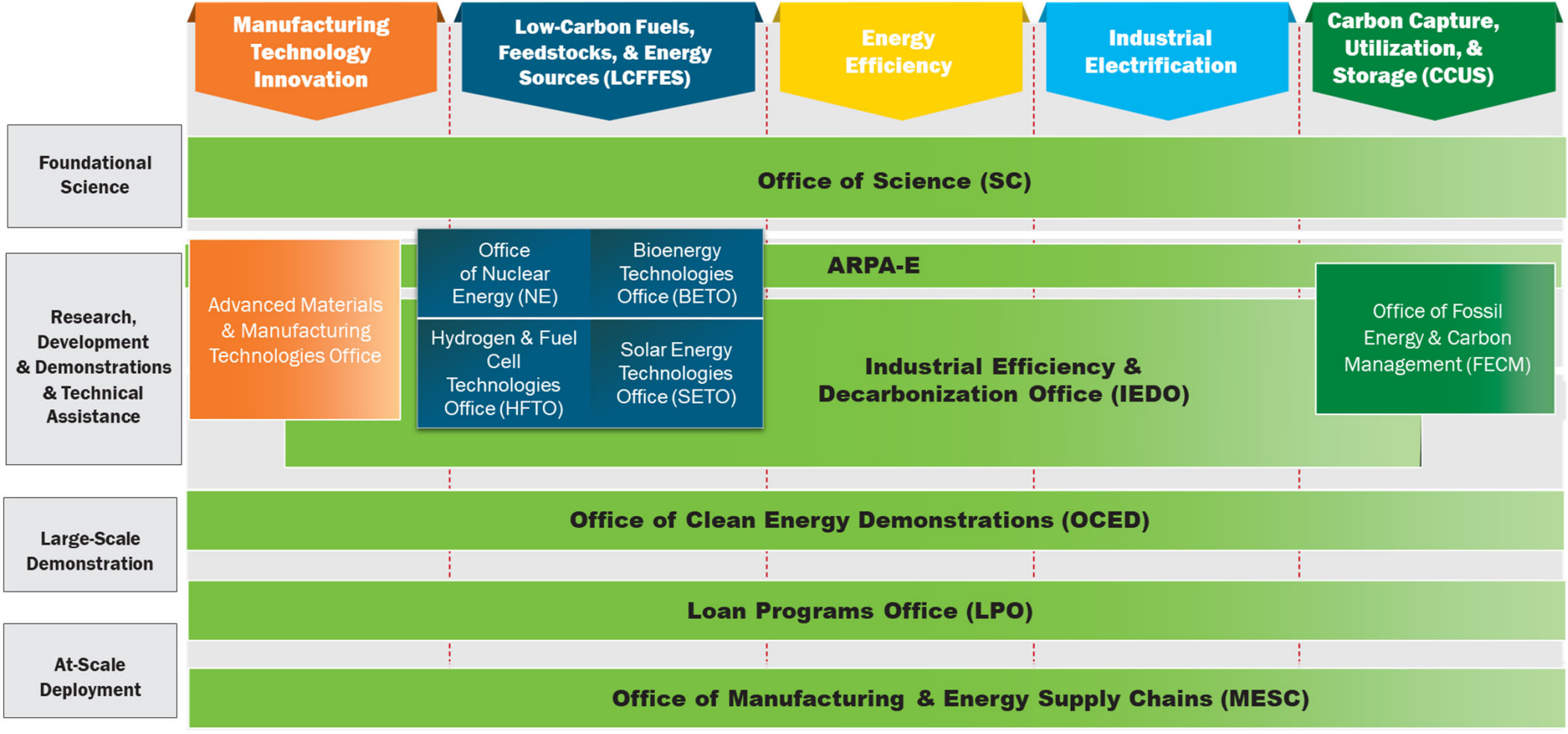
Isaac Chan
Program Manager
Cross-Sector Technologies

Dr. Paul Majsztrik
Program Manager
Energy- and Emissions-Intensive Industries

Anne Hampson
Program Manager
Technical Assistance and Workforce Development
Acting Program Manager
Technical Project Officers

Mattie Gainer
Strategic Communications Lead

DOE Offices Share a Common Strategic Framework



Energy- and Emissions-Intensive Industries

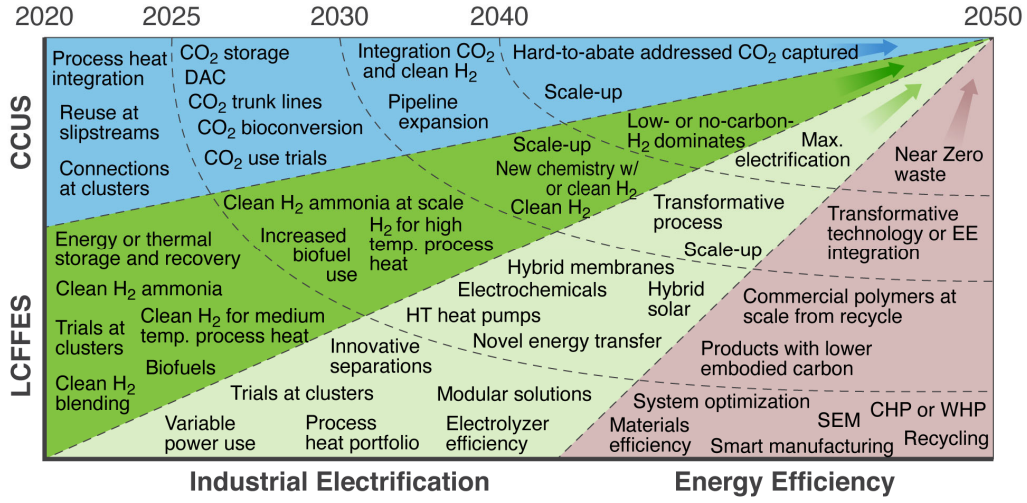
Dr. Paul Majsztrik
Program Manager

IEDO accelerates the readiness of emerging, industry-specific technologies to decarbonize the most energy- and emissions-intensive industrial subsectors

CHEMICALS (including production of low-carbon fuels)	IRON AND STEEL	CEMENT AND CONCRETE	FOOD AND BEVERAGE	FOREST PRODUCTS
				
4,842 Tbtu 332 MMT CO_2e	1,469 TBtu 100 MMT CO_2e	367 TBtu 66 MMT CO_2e	1,935 TBtu 96 MMT CO_2e	2,883 TBtu 80 MMT CO_2e

DOE *Manufacturing Energy and Carbon Footprint*, based on EIA Manufacturing Energy Consumption Survey (MECS) data for 2018

Chemicals and Refining



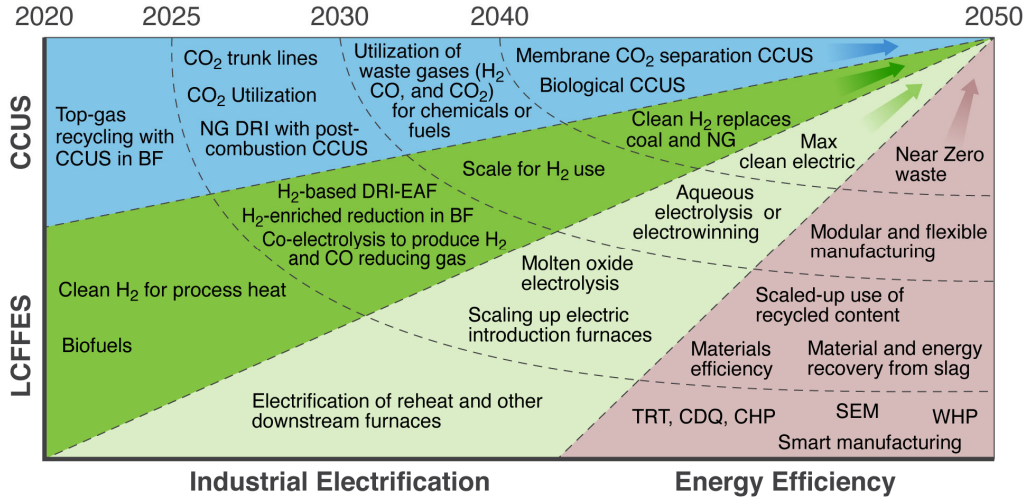
Strategic Considerations

- Address the full chemicals value chain — **decarbonization of building block chemicals** will cascade throughout industry.
- Target **high-volume, high-emitting**, energy-intensive chemicals processes.
- Focus on **unit operations applicable across multiple types** of chemicals.

Technology Development Priorities

Novel reactor, process, and catalyst designs for process intensification to enable alternative pathways	**Advanced separations** including membranes and advanced distillation
Alternative feedstocks including bio-based feedstocks, low carbon hydrogen for feedstocks, CO_2, recycled plastics, chemicals/petroleum refining biproducts	**Alternative production methods** including electrified crackers and biomanufacturing
Electrochemical processes to produce high-volume chemicals, including ethylene and nitrogenous fertilizers	**Low carbon process heating** appropriate for distributed temperature ranges in refining and chemicals manufacturing processes

Iron and Steel



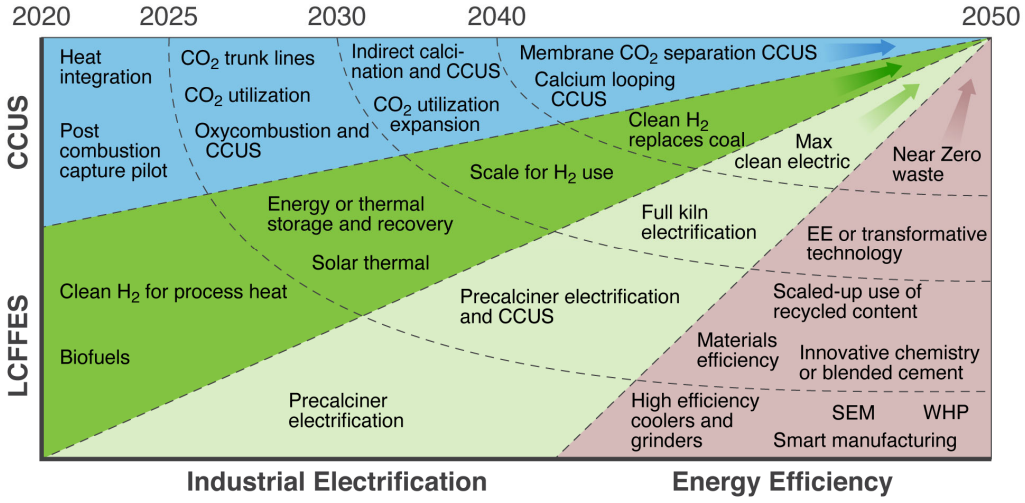
Strategic Considerations

- US steel industry has high adoption of EAFs; remaining emissions must be addressed by **next-generation processes**
- 45 MMT CO_2e of **process-related emissions** are generated as byproducts of certain processes.

Technology Development Priorities

Alternative reductants for reduction processes (DRI and HBI).	**Transformational EAF technologies** including continuous steelmaking and inert electrodes.
Electrochemical and electrification technologies including electrolysis and electric reheat/post-heat treatment furnaces.	**Plant system improvements** to enable integration of low carbon fuels, new feedstocks, and CCUS technologies.
Alternative feedstocks for EAF and BF-BOF, including BF alternative injection, coke substitution, and variable metallic feedstock.	**Increase scrap recycling** through development of technologies that address contaminants.

Cement and Concrete



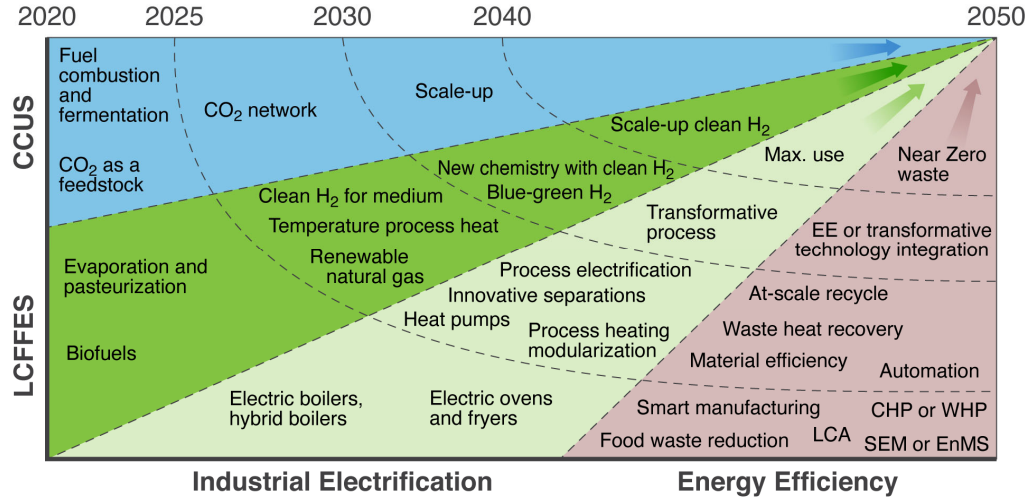
Strategic Considerations

- Cement industry is comprised of mature, capital-intensive plants built to operate for more than 50 years.
- ~60% of the CO2 emitted is from direct process emissions released during calcination (decomposition of limestone in clinker).

Technology Development Priorities

Novel chemistries and materials to substitute high CO_2 emitting clinker in cement.	**Low-carbon fuels** for pre-calciner and kiln including hydrogen, waste fuels, and bio-based fuels.
Innovative clinker production technology including substitutions to reduce energy/emissions of production.	**Carbon capture and utilization approaches** including utilization of CO_2 for **concrete curing and mineralization** and equipment modifications for purified CO_2 from the pre-calciner.
Electrochemical and other low-carbon process routes for direct-to-cement product or for lime/clinker feedstock.	

Food and Beverage *and* Forest Products

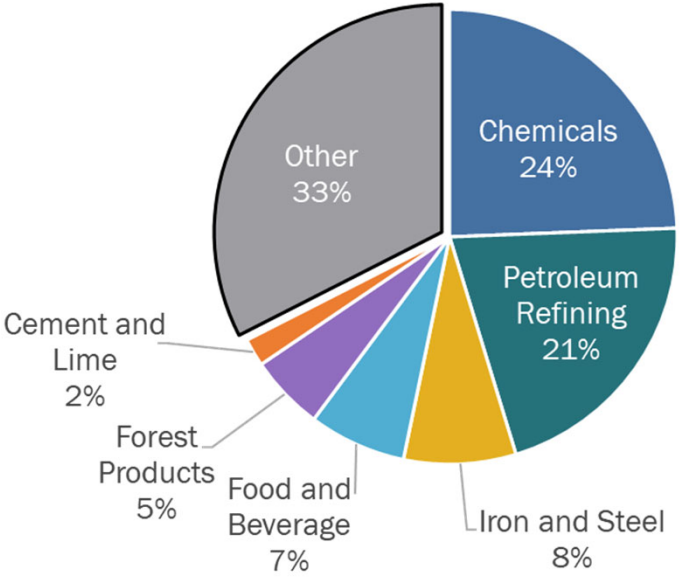


Technology Development Priorities (Food/Beverage)
Thermal and drying technologies for low temperature demands of food and beverage products
Bio-chemical processing techniques to reduce processing time, energy consumption, and pollutant emissions
Advanced membrane technologies for separations
Waste reduction in both food and beverage processing and packaging through increased recycling, alternative thermal packaging, and supply chain improvements

Technology Development Priorities (Forest Products)
Transformative drying and energy recovery techniques including heat pump drying, waste heat recovery, electrification, new energy sources for steam and gas-fired dryers
Novel pulping chemistries to improve yield and energy intensity, e.g. biological or catalyst-assisted pulping, deep eutectic solvents
Paper forming and dewatering technologies to reduce drying demand including multi-phase forming, optimized fiber dewatering in pressing
Advanced separations and alternative fuels in chemical recovery including membrane separation of black liquor and bio-fuel use

Other Sectors

Other Sectors produce 371 MMT CO_2 of energy related emissions annually.
Includes energy/carbon-intensive include aluminum, glass, and metal casting



Technology Development Priorities
Novel melting and furnace technologies to reduce energy intensity of processing or electrifying the process.
Decarbonization of downstream processes such as glass tempering, glass lehrs, aluminum solution treatment, iron foundry cupolas, and casting and extrusion technologies.
Low-carbon fuels including clean hydrogen, bio-based, and waste gases for use in production furnaces.
Electro-chemical technologies such as novel cathode materials.
Alternative processing approaches such as thermo-magnetic processing.
Emerging energy consumers such as information and data collection and advanced data centers.

Cross-Sector Technologies

Isaac Chan
Program Manager

IEDO accelerates the readiness of energy- and emissions-reducing components, systems, and operational technologies, across a broad range of industries

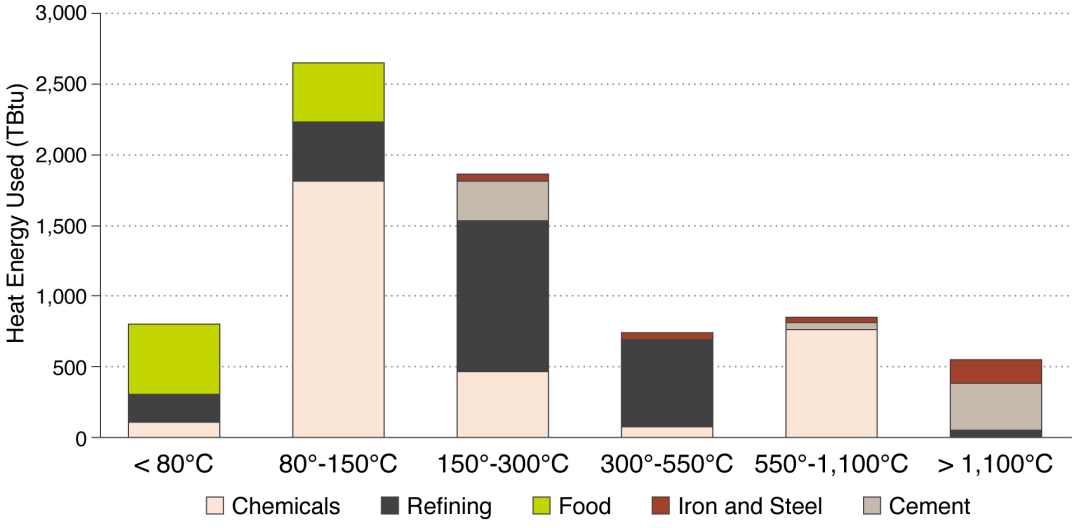
THERMAL PROCESS AND SYSTEMS

LOW CARBON FUELS, FEEDSTOCKS, AND ENERGY SOURCES

EMERGING EFFICIENCY

WATER AND WASTEWATER TREATMENT

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.

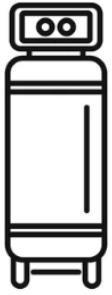
Membrane technologies that utilize mechanical and electrical instead of thermal energy for separations in several industries.

Low Carbon Fuels and Feedstocks and Energy Sources

Technology Development Priorities
Renewable fuel burner and furnace equipment utilizing biogas and hydrogen blends to replace natural gas-fired equipment.
Develop innovative equipment technologies and auxiliary components to enable use of LCFFES
Renewable thermal energy technologies such as geothermal or concentrated solar energy, especially for process heating applications.
Clean hydrogen for industrial applications, including for process heat and material feedstocks.
Flexible combined heat and power (CHP) systems that can provide dispatchable onsite power.

Piping: New materials to prevent corrosion and embrittlement

Hydrogen Valves/Gaskets: New materials required to prevent leakage



Hydrogen Compressors: Lower volumetric energy density requires movement of 3x more gas for same heating content

Sensors and Controls: Air/fuel flow control for variable H_2 supply, advanced exhaust damper controls, leak detection, and safety monitoring

Flame Detection: Lower flame visibility requires equipment for real time sensing to prevent flame out

Exhaust: Higher moisture content in exhaust requires condensing equipment or gas reheating

Emerging Efficiency and Other Decarbonization Technologies

Technology Development Priorities
Waste heat recovery and usage such as advanced heat exchanger systems, and advanced cycles and thermoelectric systems to convert waste heat to electricity.
Thermal energy storage either from electricity or heat recovered from processes.
Industrial load flexibility (i.e., novel core unit operations that can run on flexible inputs) to increase renewable penetration and facility resilience.
Smart and digital manufacturing, which leverage cyber-physical systems for delivering consistent product quality and resource efficiency.

Water and Wastewater Treatment

Technology Development Priorities
Desalination and water-treatment technologies to secure affordable and energy-efficient water supplies from nontraditional water sources
Reduction in the mass of sludge or biosolids requiring disposal.
Reduction or elimination of aeration in the wastewater treatment process, which consumes as much as 80% of the electricity demand in WRRFs during secondary treatment and conventional biological nitrogen removal.
Energy recovery from wastewaters. Conventional anaerobic digestion does not capture all the energy in wastewater and is economically challenging at smaller scales.
Produce high-value products from wastewater, including N- and P-based nutrients, that have the potential to supplant fossil fuel-derived products.

NAWI

National Alliance
for Water Innovation

- 5-Year, $110M+ Energy-Water Desalination Hub
- $23 million in cost share support from state agencies
- Goal: 75% reduction in cost and energy of desalination

Technical Assistance and Workforce Development

Anne Hampson
Program Manager

TECHNICAL ASSISTANCE

Partner with and enable industry to accelerate the adoption of technologies, programs, and best practices that improve efficiency and decarbonization.

WORKFORCE DEVELOPMENT

Promote the development of a diverse mix of new workers and upskill existing workers for the industrial jobs of today and the future.

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
- Energy and Decarbonization boot camps

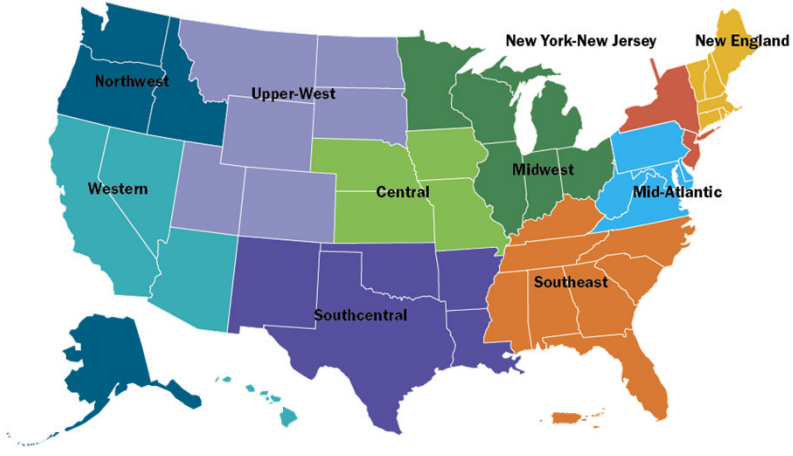
IEDO Onsite Energy Program

The Onsite Energy Program is a new initiative to provide technical assistance for 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:

- Deploy onsite renewable energy and storage technologies
- Identify cost-effective options for achieving clean energy targets
- Highlight pathways for accelerating the integration of onsite clean energy technologies
- Reduce greenhouse gas emissions while prioritizing energy justice and workforce development



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

- Application Deadline: October 25, 2022
- Selections Anticipated: March, 2023

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
- Letter of Intent Deadline: February 28, 2023
- Application Deadline: April 21, 2023
- Selections Anticipated: June/July, 2023

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

- Concept Paper Deadline: January 27, 2023
- Application Deadline: April 3, 2023
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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.

- Concept Paper Deadline: October 12, 2022
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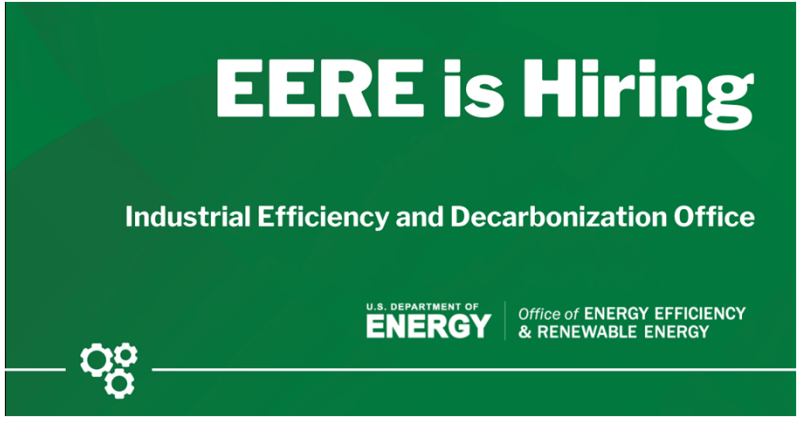
IEDO Career Opportunities

- Technical Project Officers (2 open positions)
- Energy- and Emissions Intensive Industries Sr. Technology Manager
- Technical Assistance and Workforce Development Technology Manager
- Cross Sector Technologies Technology Manager (2 open positions)
- Energy- and Emissions-Intensive Industries Technology Manager

Interested in applying? Learn more at our careers page: www.energy.gov/eere/amo/advanced-manufacturing-industrial-decarbonization-careers

Email: AMOJobs@ee.doe.gov



ORISE Science, Technology, and Policy Fellowship

Develop leadership skills by designing and implementing national research and development (R&D) programs.

Strategic Areas Include:

- Industry-specific decarbonization and energy efficiency technologies
- Process heating efficiency and decarbonization
- Low-carbon fuels and feedstocks
- Water and wastewater decarbonization RD&D
- Industrial energy efficiency
- Industrial technical assistance and workforce development
- Communications, Environmental Justice, and Stakeholder Outreach

Eligibility:

- Open to physical, natural, and social scientists, engineers, and entrepreneurs with bachelor's, master's or doctoral degrees and established professionals with post-grad experience. Must be a U.S. Citizen or have Permanent Resident status.

Benefits:

- Competitive Stipend
- Mentorship from DOE officials
- Travel allowance
- Health insurance supplement
- Relocation Expenses

Apply now:

https://www.zintellect.com/Opportunity/Details/DOE-EERE-STP-IEDO-2023-1100

Thank you

Avi Shultz, Deputy Director
Industrial Efficiency and Decarbonization Office
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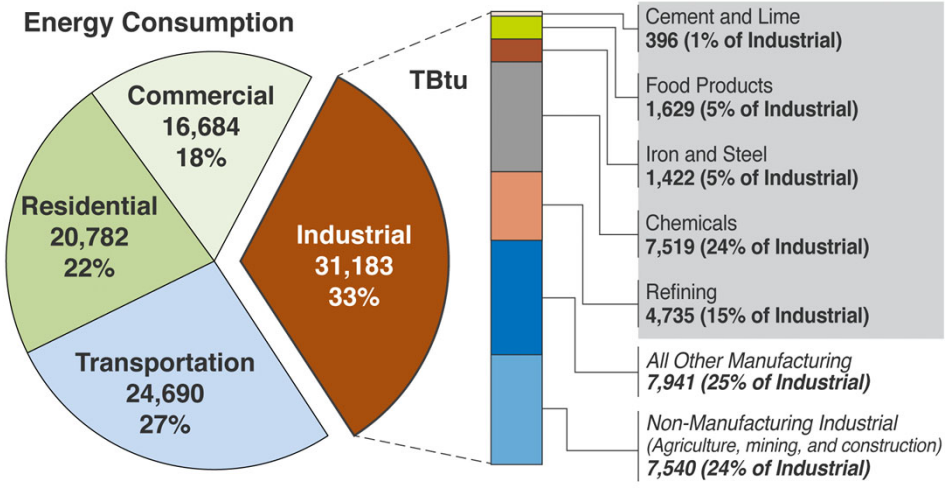
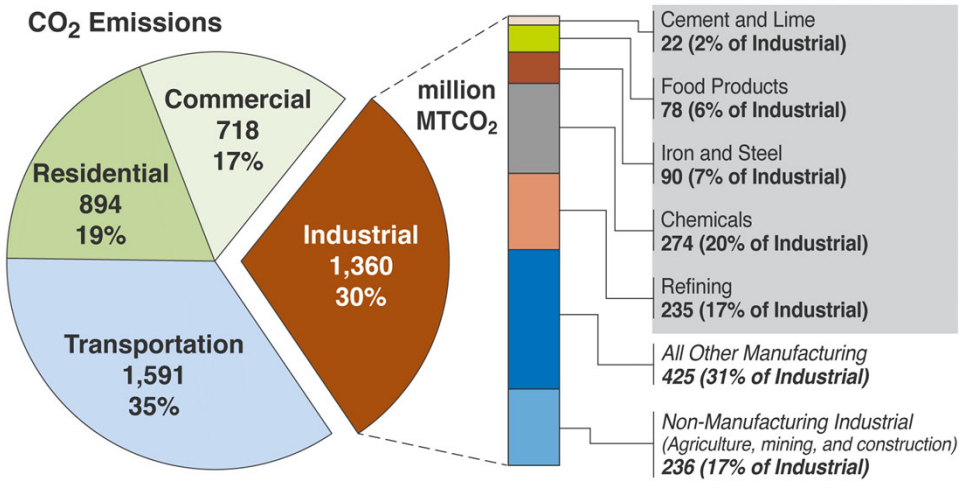
Industry Contributes Significantly to CO_2 Emissions





The five top industrial sectors are responsible for 51% of the industrial contribution to CO_2 emissions

Data source: Energy Information Administration (EIA) *Annual Energy Outlook 2021 with Projections to 2050*.

Role of DOE's Technology Development Programs