Onsite Energy Technical Assistance Partnerships
U.S. DEPARTMENT OF ENERGY
Midwest

Empowering Energy-Intensive Facilities: Onsite Solutions for Decarbonization

2024 Energy Efficiency & Technology Conference
CenterPoint Energy

May 22, 2024

Agenda

- What are the U.S. DOE Onsite Energy TAPs?
- What are the U.S. DOE's four (4) pillars to industrial decarbonization?
- What onsite energy technologies can help energy intensive users meet their decarbonization goals?
- What no-cost services are available through the U.S. DOE Onsite Energy TAPs provide?

Onsite Energy Program

The U.S. Department of Energy's (DOE) Onsite Energy Program provides technical assistance, market analysis, and best practices to help industrial facilities and other large energy users increase the adoption of onsite clean energy technologies.

battery storage | combined heat and power | district energy | fuel cells | geothermal | industrial heat pumps

renewable fuels | solar PV | solar thermal | thermal storage | waste heat to power | wind

Onsite Energy Technical Assistance Partnerships (TAPs)

DOE's 10 regional Onsite Energy TAPs provide technical assistance to end users and other stakeholders about technology options for achieving clean energy objectives. Key services include:

Technical Assistance: Screen sites for opportunities to implement onsite energy technologies and provide advanced services to maximize economic impact and reduce risk from initial screening to installation to operation and maintenance.

End-User Engagement: Partner with organizations representing industrial and other large energy users to advance onsite energy as a cost-effective way to transition to a clean energy economy.

Stakeholder Engagement: Engage with strategic stakeholders, including utilities and policymakers, to identify and reduce barriers to onsite energy through fact-based, unbiased education.

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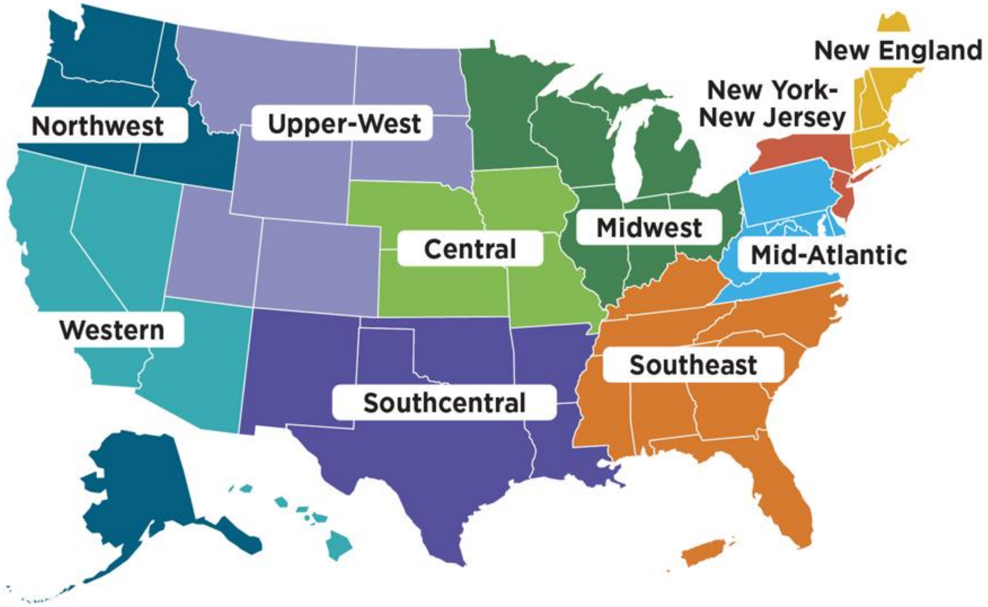

https://betterbuildingssolutioncenter.energy.gov/onsite-energy/taps

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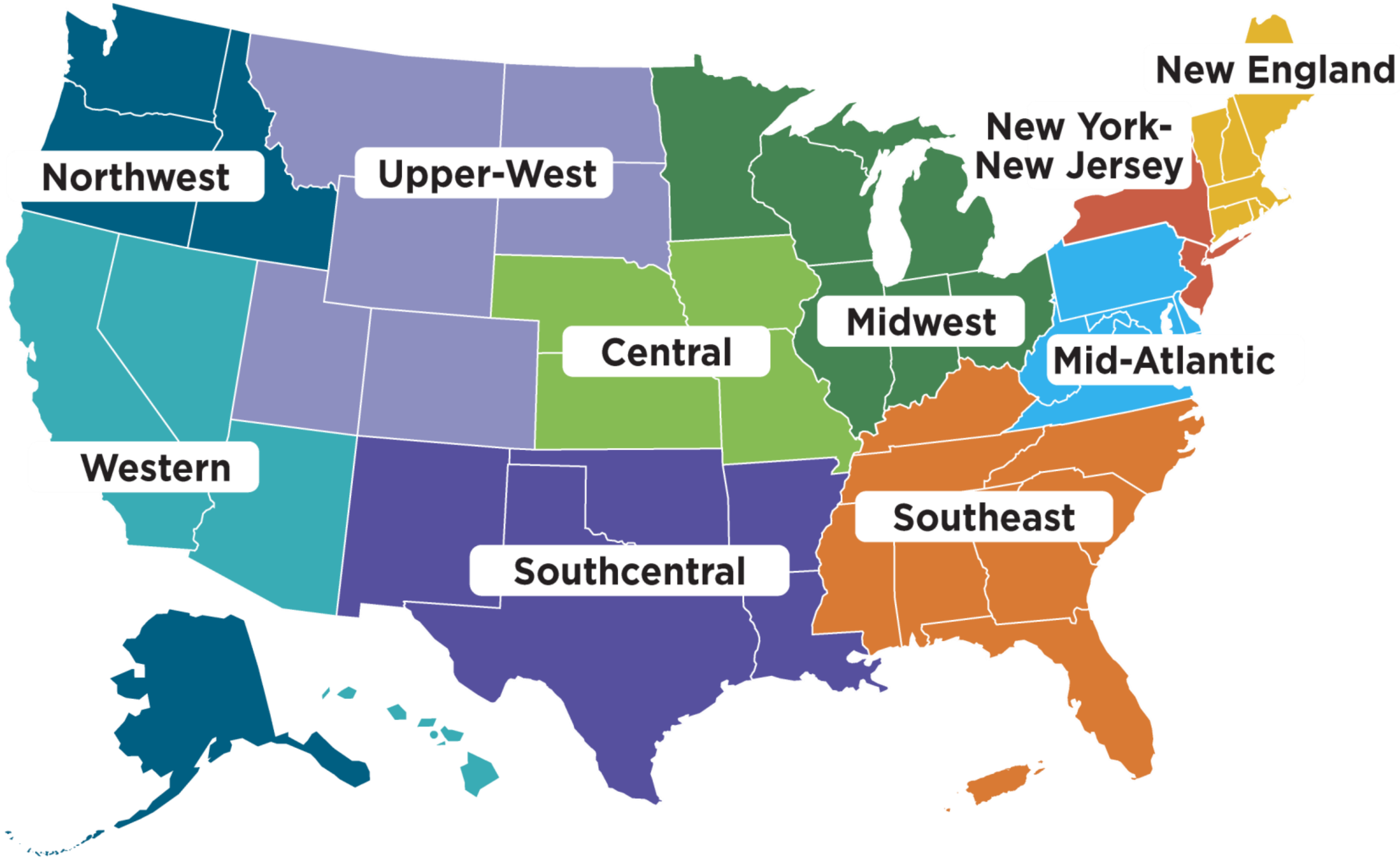

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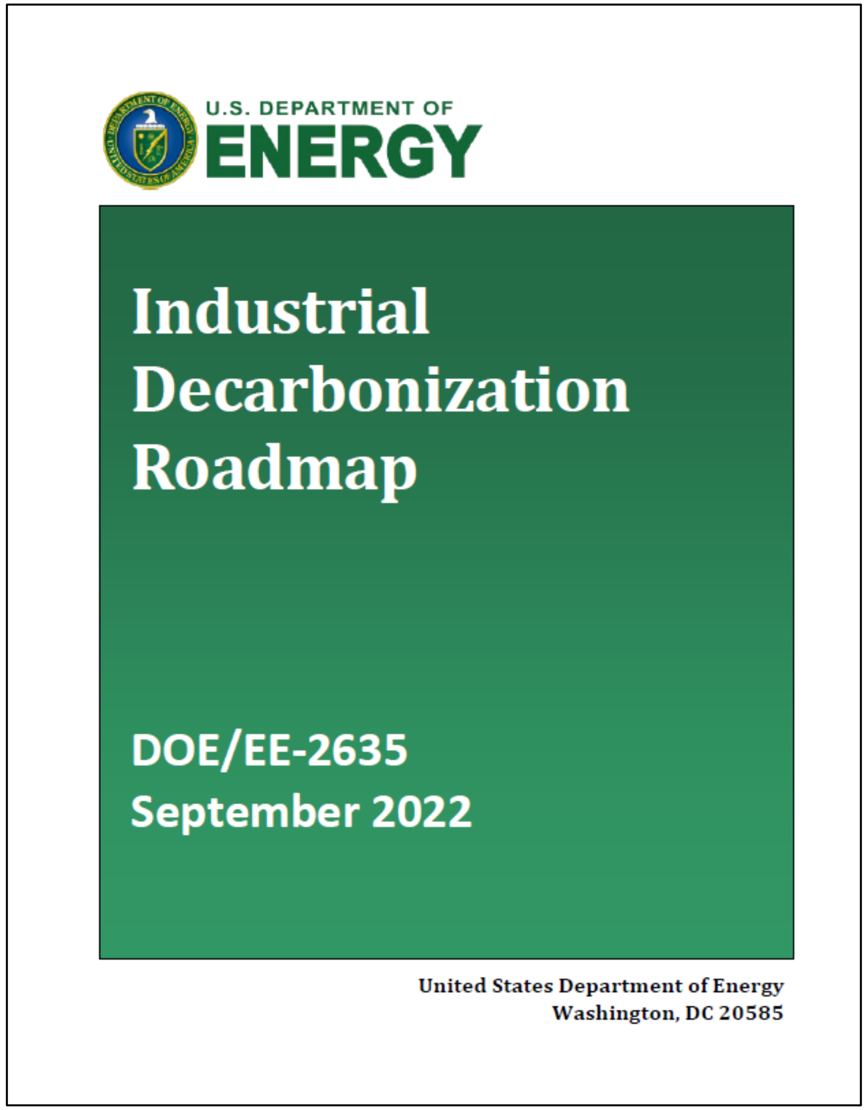
U.S. DOE Technology Pathways of Industrial Decarbonization

U.S. DOE "Industrial Decarbonization Roadmap"


U.S. DEPARTMENT OF ENERGY

Industrial Decarbonization Roadmap

DOE/EE-2635
September 2022

United States Department of Energy
Washington, DC 20585

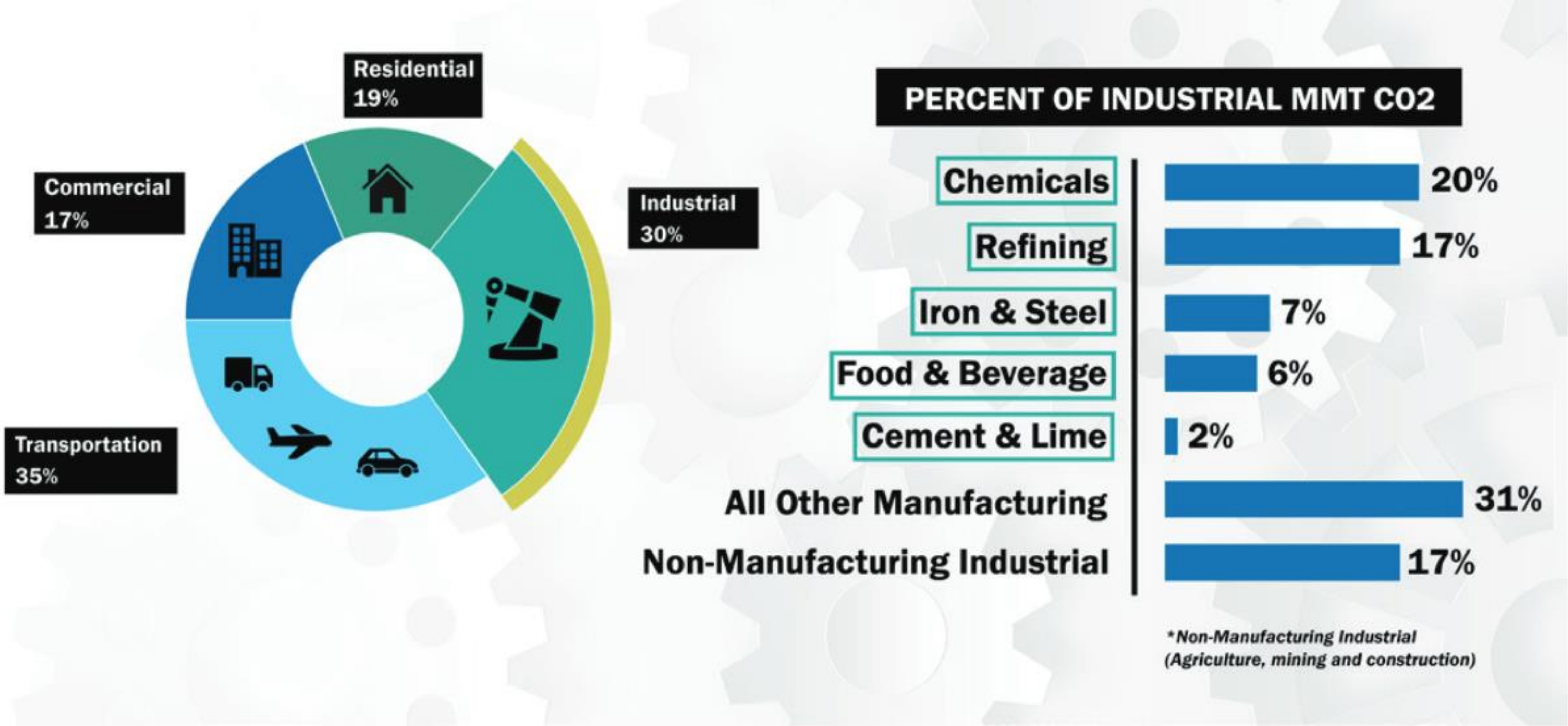
"The science is clear that significant greenhouse gas (GHG) emissions reductions are needed to moderate the severe impacts of ongoing climate change."

"The industrial sector is the backbone of America's economy… however, the industrial sector currently accounts for **approximately one third of our nation's energy-related carbon dioxide (CO2) emissions**."

"The U.S. industrial sector is considered a **'difficult-to-decarbonize' sector** of the energy economy, in part because of the diversity of energy inputs that feed into a heterogenous array of industrial processes and operations."

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

U.S. Primary Energy-Related CO2 Emissions by Economic Sector



Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Distribution of Process Heat Temperature Ranges by Industrial Subsector

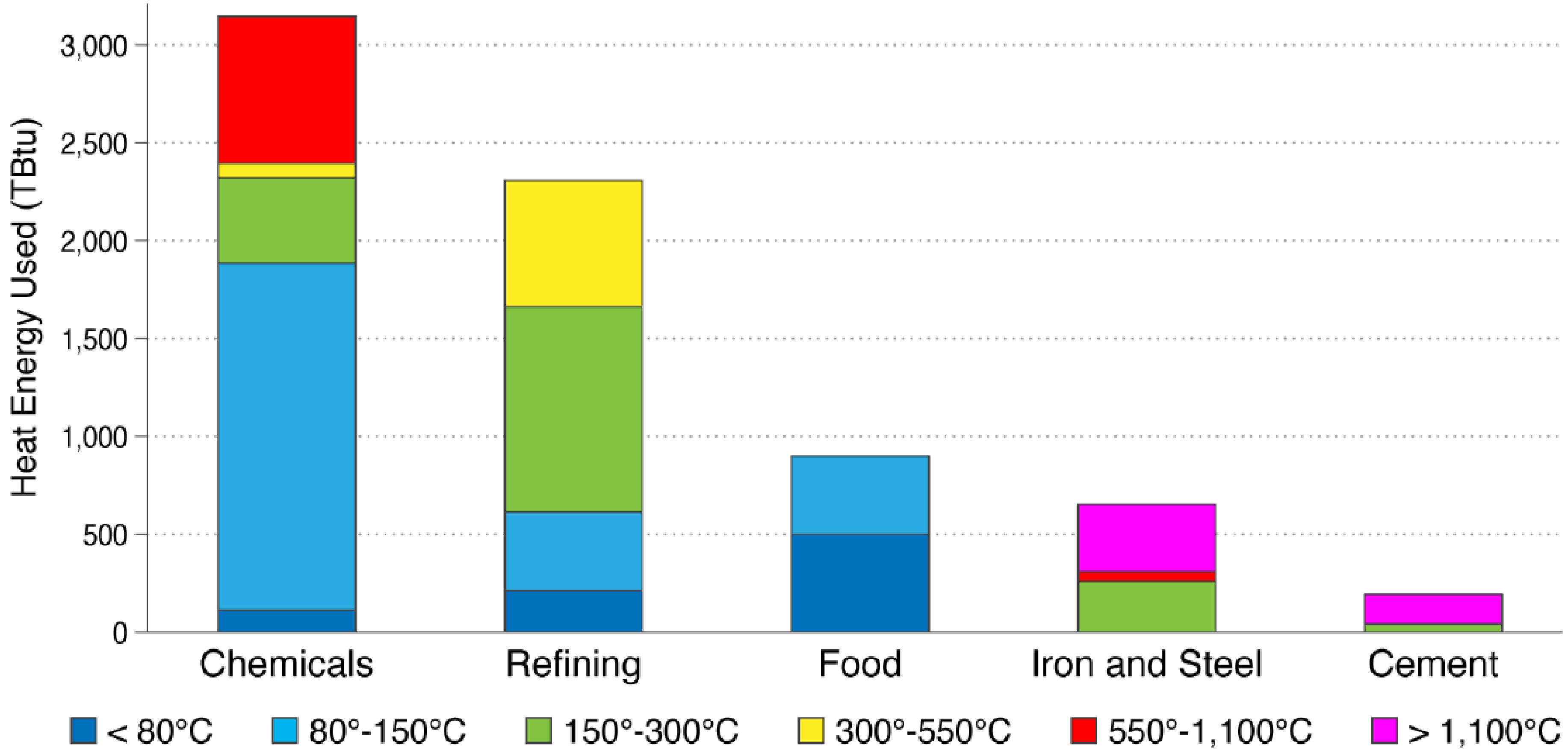


FIGURE 6. DISTRIBUTION OF PROCESS HEAT TEMPERATURE RANGES BY INDUSTRIAL SUBSECTOR IN 2014.

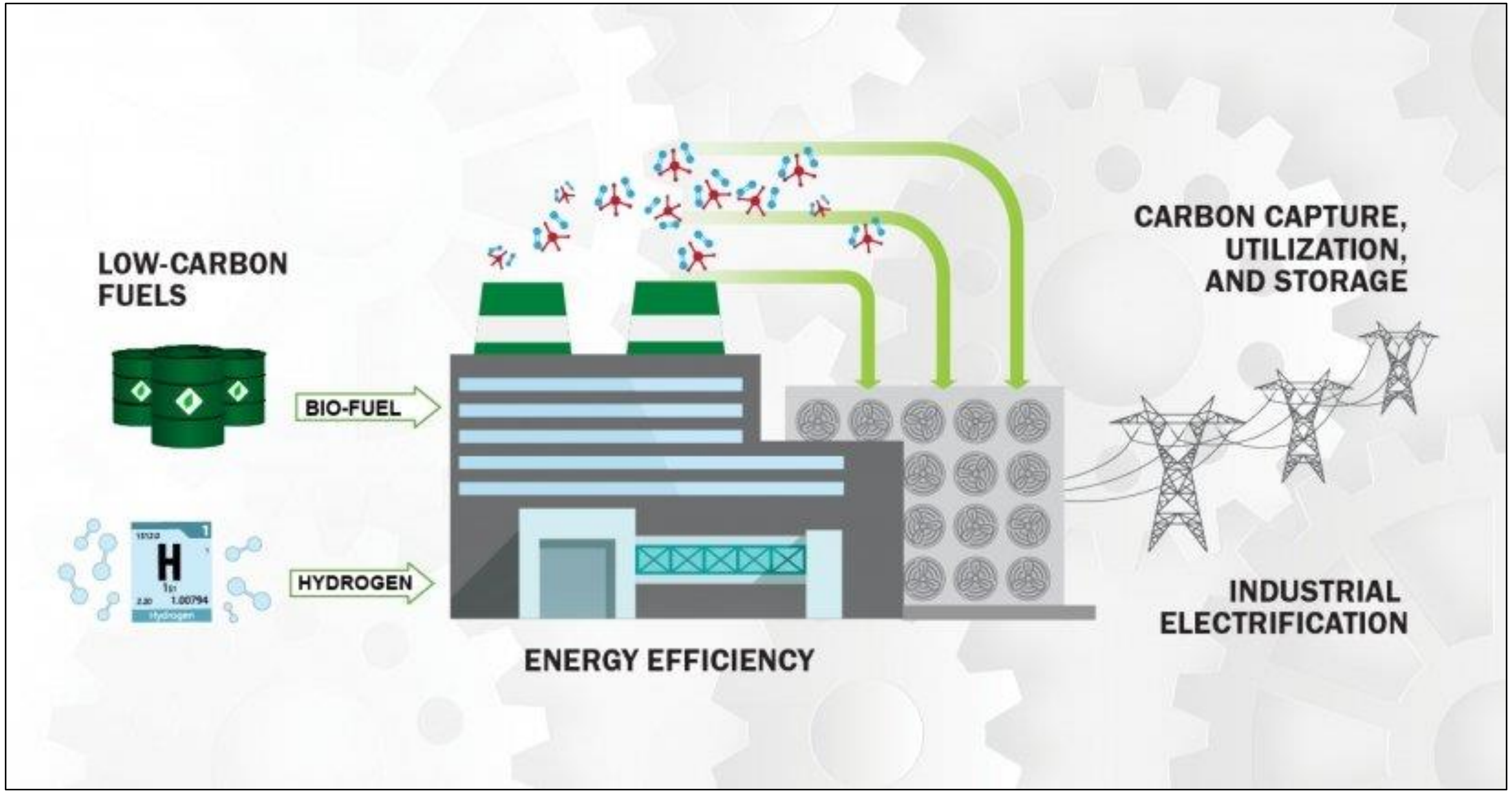
TEMPERATURE RANGES ARE IN °C AND HEAT USE IS IN TRILLION BTU (TBTU). DATA SOURCE: MCMILLAN 2019[81]

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

U.S. DOE Strategies for Decarbonizing U.S. Industries

The DOE Industrial Decarbonization Roadmap identifies 4 key technological pillars to significantly reduce emissions for the five subsectors studied. With the application of alternative approaches, 100% of annual CO2 emissions could be mitigated. Key pillars include:

1. Energy Efficiency
2. Industrial Electrification
3. Low-Carbon Fuels, Feedstocks, and Energy Sources (LCFFES)
4. Carbon Capture, Utilization, and Storage (CCUS)



Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Key Decarbonization Technology Pillars – Pillars 1 & 2

Photo: https://www.energy.gov/mesc/industrial-assessment-centers-iacs

1) Energy Efficiency

- Greatest opportunities for near-term decarbonization solutions
- In many cases, does not require major changes to industrial processes

Key energy efficiency efforts include:

- Improvements in system efficiencies, process yield, and recovery of thermal energy;
- Expansion of energy management practices;
- Increased implementation of smart manufacturing strategies designed to reduce energy consumption.

Photo: https://www.purdue.edu/research/

2) Industrial Electrification

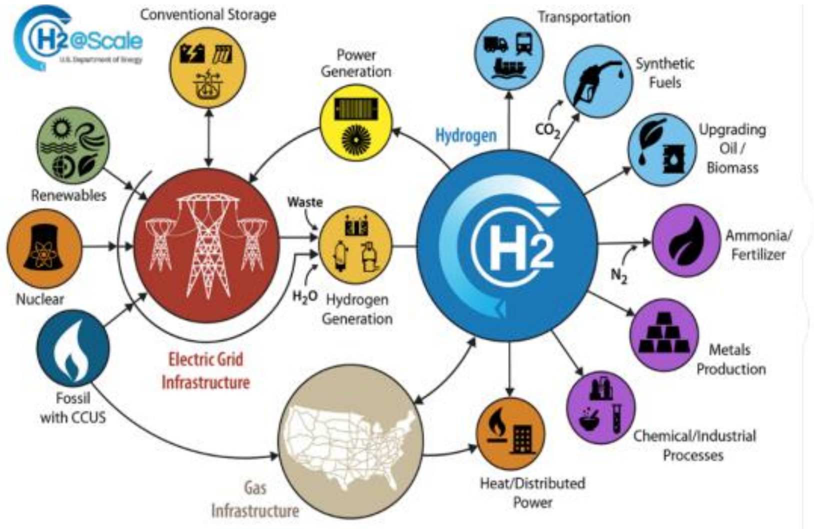
- Over 50% of all manufacturing energy is used for thermal processing (<5% of these operations are electrified)
- Electrification, particularly of thermal processes, provides an opportunity to leverage decarbonized and inexpensive electricity sources

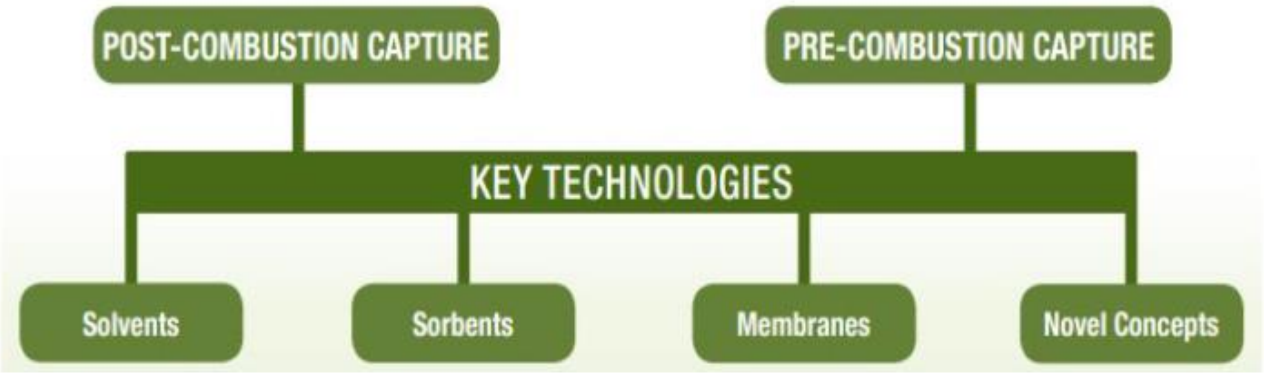
Key electrification efforts include:

- improving the energy efficiency of existing electrotechnologies or hybrid systems,
- innovating new electric or hybrid systems,
- overcoming economic and technical barriers to implementing electrotechnologies in existing fossil-based processing systems.

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Key Decarbonization Technology Pillars – Pillars 3 & 4





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

- Includes fuel-flexible processes, clean hydrogen fuels and feedstocks, biofuels and biofeedstocks, nuclear, concentrating solar power, and geothermal.

Key energy efficiency efforts include:

- Development of fuel-flexible processes
- Integration of hydrogen fuels and feedstocks into industrial applications
- Reducing hydrogen cost to $1 per kg and improving efficiency and durability of low- and high-temperature electrolyzers.
- Use of biofuels and bio feedstocks

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

4) Carbon Capture, Utilization, and Storage (CCUS)

- Predicted to be the largest source of long-term emission reductions (in the DOE roadmap)
- Both carbon utilization and carbon storage will be critical to achieving the final carbon reductions
- Examples include post-combustion chemical absorption of CO2 or construction of CO2 pipelines and other supportive infrastructure

Key CCUS efforts include:

- Improving efficiency, economic viability, and safety
- Improvements to catalysts and process designs are critical to higher efficiency levels, lower costs, and lower material consumption or waste production.

Summary of 4 Strategic Industrial Decarbonization Pillars

	Energy Efficiency	Industrial Electrification	Low-Carbon Fuels, Feedstocks, and Energy Sources (LCFFES)	Carbon Capture, Utilization, and Storage (CCUS)
Summary	Energy efficiency is a foundational, crosscutting decarbonization strategy and is the most cost-effective option for GHG emission reductions in the near term.	Leveraging advancements in low-carbon electricity from both grid and onsite renewable generation sources will be critical to decarbonization efforts.	Substituting low-and no-carbon fuel and feedstocks reduces combustion associated emissions for industrial processes.	CCUS refers to the multi-component strategy of capturing generated carbon dioxide (CO2) from a point source and utilizing the captured CO2 to make value added products or storing it long-term to avoid release.
Decarbonization Efforts	• Strategic energy management approaches to optimize performance of industrial processes at the system-level • Systems management and optimization of thermal heat from manufacturing process heating, boiler, and combined heat and power (CHP) sources • Smart manufacturing and advanced data analytics to increase energy productivity in manufacturing processes	• Electrification of process heat using induction, radiative heating, or advanced heat pumps • Electrification of high-temperature range processes such as those found in iron, steel, and cement making • Replacing thermally-driven processes with electrochemical ones	• Development of fuel-flexible processes • Integration of hydrogen fuels and feedstocks into industrial applications • The use of biofuels and bio feedstocks	• Post-combustion chemical absorption of CO2 • Development and manufacturing optimization of advanced CO2 capture materials that improve efficiency and lower cost of capture • Development of processes to utilize captured CO2 to manufacture new materials

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Path to Net-Zero Industrial CO_2 Emissions in U.S. for 5 Carbon-Intensive Industrial Subsectors

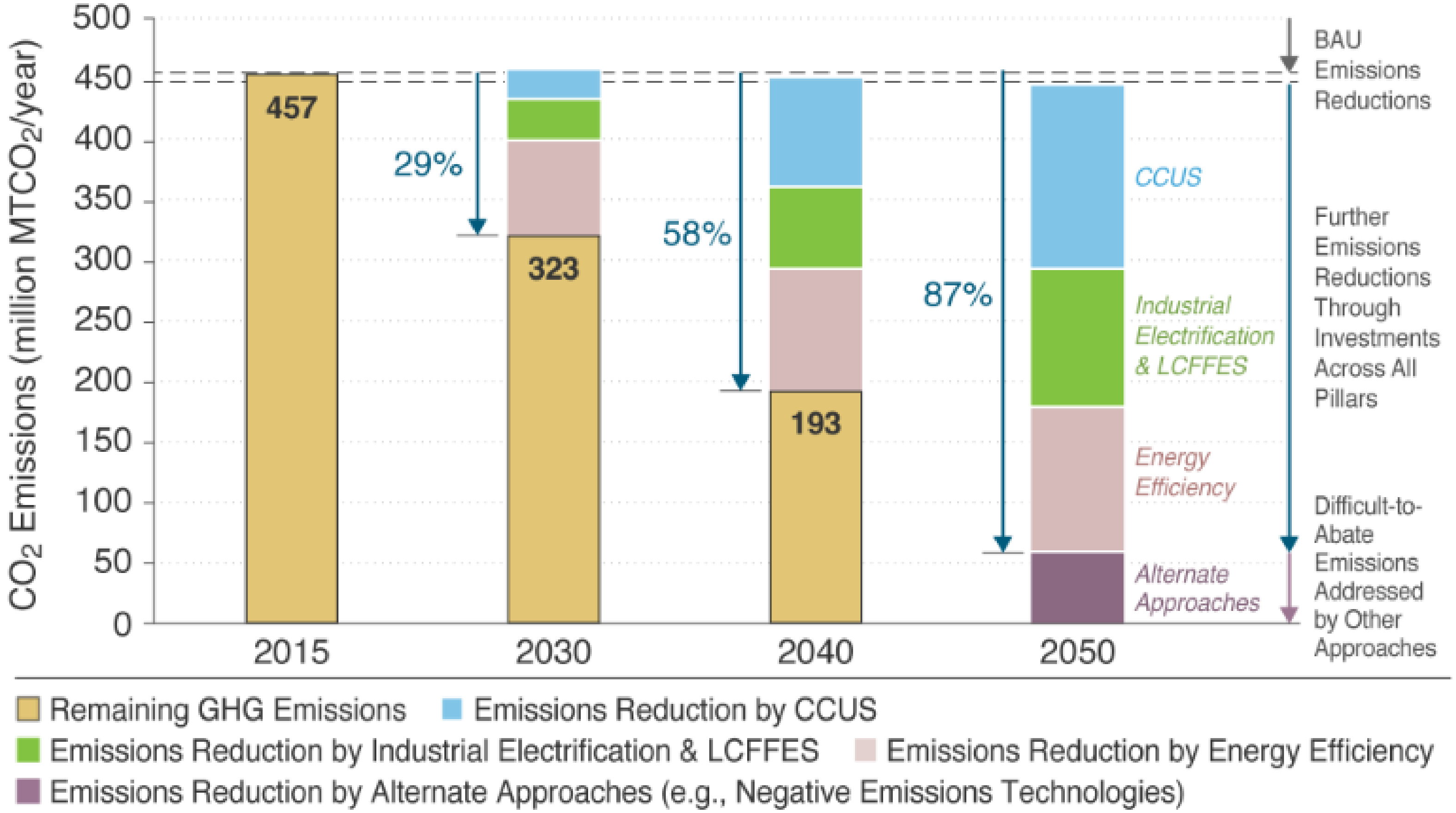


FIGURE ES 1. THE PATH TO NET-ZERO INDUSTRIAL CO_2 EMISSIONS IN THE UNITED STATES FOR FIVE CARBON-INTENSIVE INDUSTRIAL SUBSECTORS, WITH CONTRIBUTIONS FROM EACH DECARBONIZATION PILLAR: ENERGY EFFICIENCY; INDUSTRIAL ELECTRIFICATION; LOW-CARBON FUELS, FEEDSTOCKS, AND ENERGY SOURCES (LCFFES); AND CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS)). EMISSIONS ARE IN MILLIONS OF METRIC TONS (MT) PER YEAR.

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Landscape of Major RD&D Investment Opportunities for Industrial Decarbonization across All Subsectors by Decade & Decarbonization Pillar

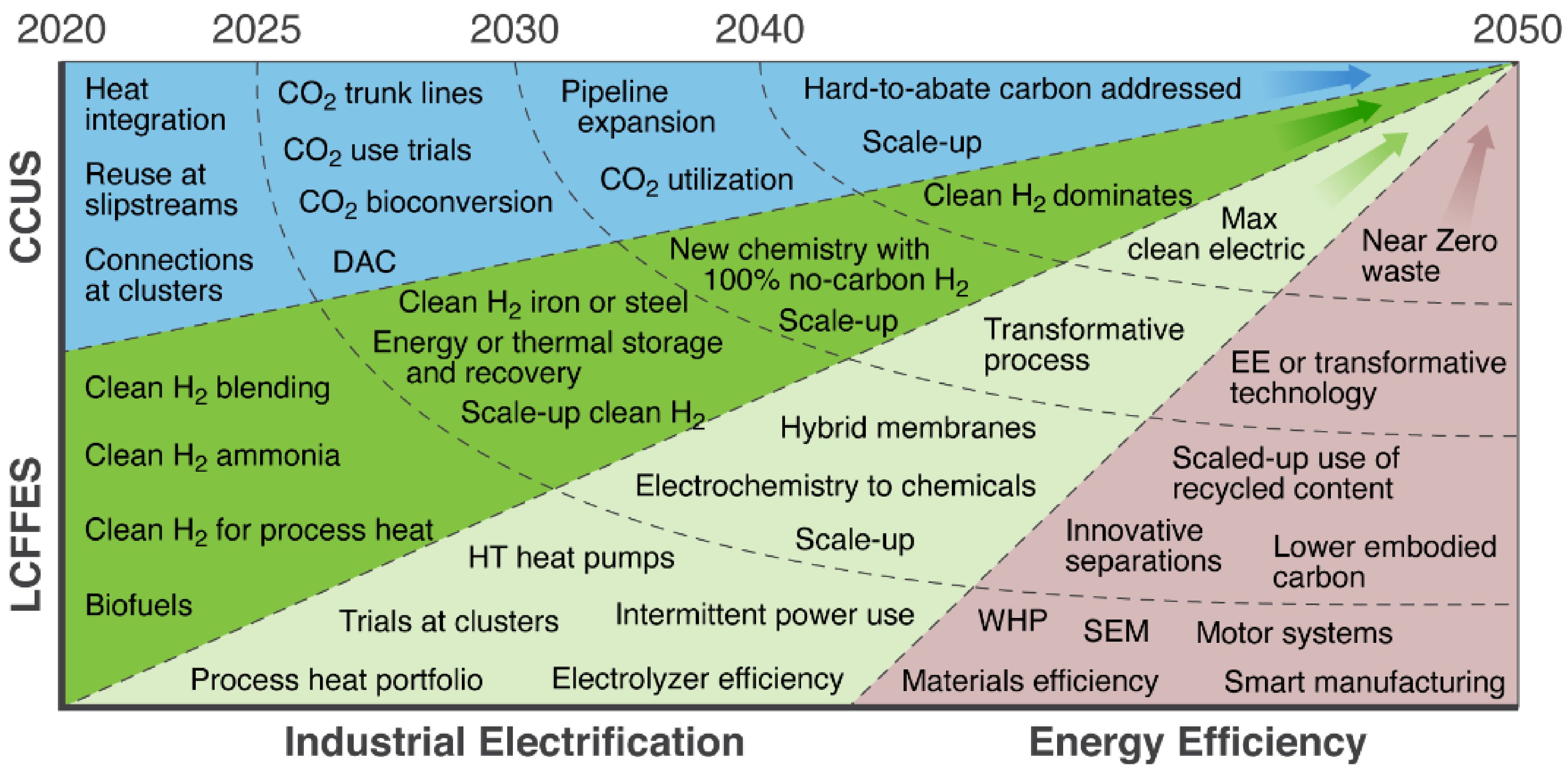


FIGURE 10. LANDSCAPE OF MAJOR RD&D INVESTMENT OPPORTUNITIES FOR INDUSTRIAL DECARBONIZATION ACROSS ALL SUBSECTORS BY DECADE AND DECARBONIZATION PILLAR.

Source: https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

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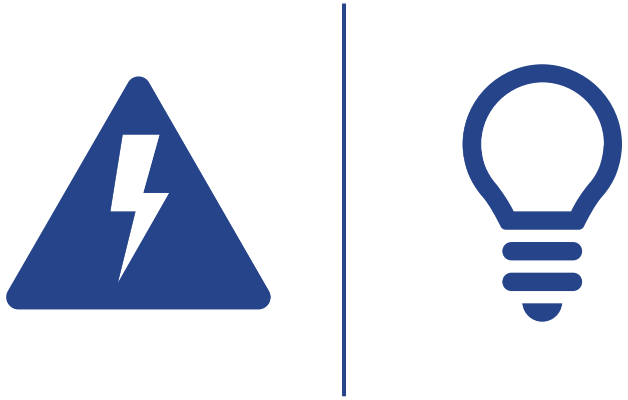
Onsite Energy Technologies that can provide Decarbonization Solutions Today

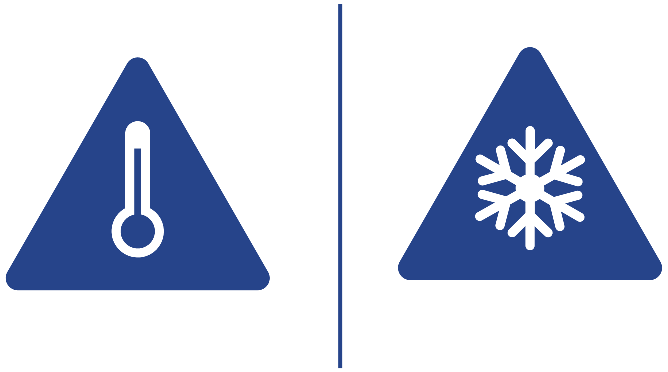
What is Onsite Energy?

- Physically located at an industrial facility or other large energy user
- Provides clean energy services directly to their site in one of more of the following forms



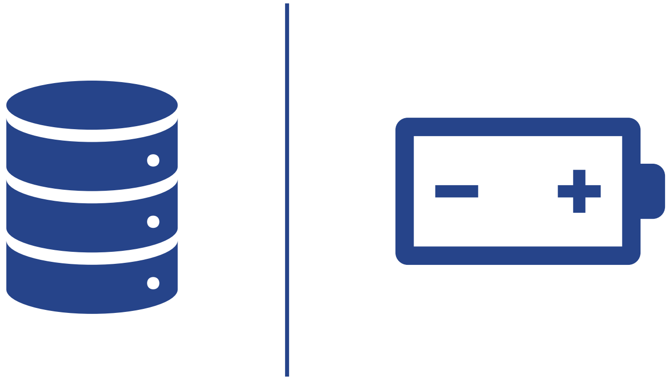
Electric Generation

- combined heat and power*
- district energy*
- fuel cells*
- renewable fuels*
- solar PV
- waste heat to power
- wind



Thermal Generation

- combined heat and power*
- district energy*
- fuel cells*
- geothermal
- industrial heat pumps
- renewable fuels*
- solar thermal



Energy Storage

- battery storage
- thermal storage
- district energy*

** These technologies may provide more than one onsite energy solution*

Why Consider Onsite Energy?

Improve Resilience

Operate with more Flexibility

Reduce Operating Costs

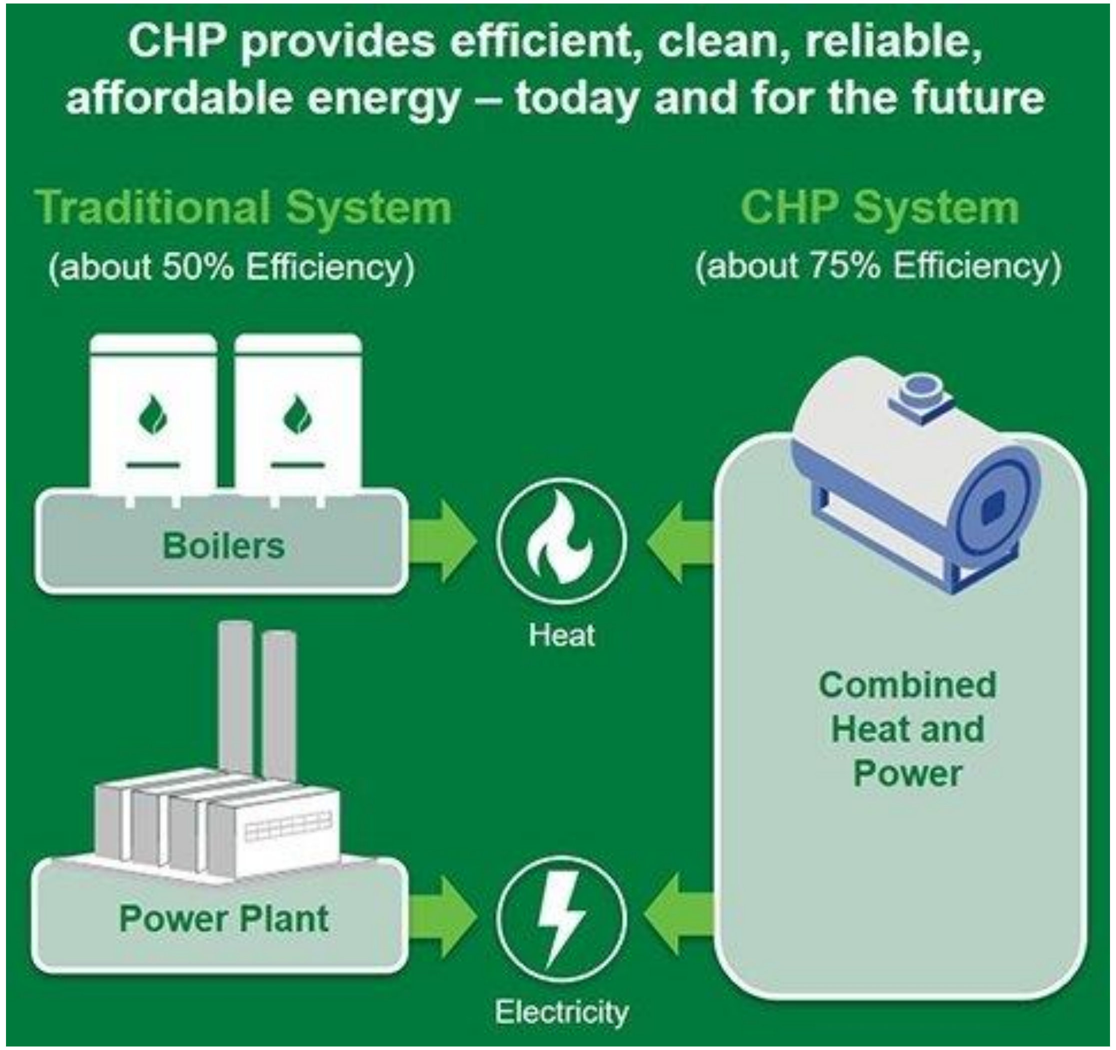
Reduce Emissions

Exploring Onsite Energy Technologies

- Onsite Energy technologies explored in this presentation
  - Combined heat and power (CHP), renewable fuels, waste heat to power (WHP), industrial heat pumps, district energy
- Other Onsite Energy technologies
  - Other Generation Solutions: fuel cells, geothermal, solar PV, solar thermal, wind
  - Storage Solutions: batteries, thermal storage
- Additional Notes
  - Multiple onsite energy technologies may be implemented together for increasing optimal benefits to a site
  - More information: https://betterbuildingssolutioncenter.energy.gov/onsite-energy

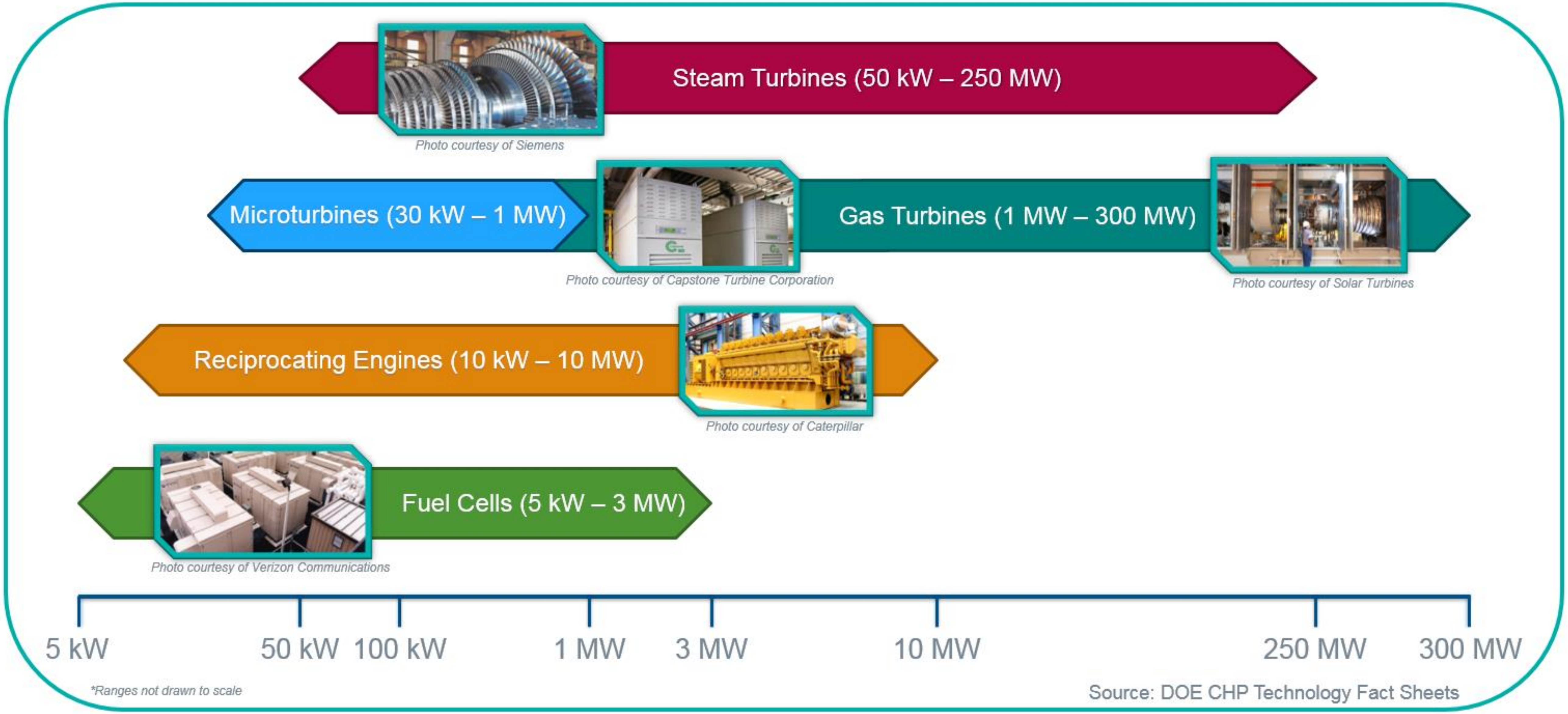
Combined Heat and Power (CHP)

- CHP produces both electricity and thermal energy onsite in a single energy-efficient process.
- Often categorized based on the type of prime mover that drives the system, including reciprocating engines, gas turbines, microturbines, fuel cells, and steam turbines.
- Can operate on various fuels—including natural gas, biogas, renewable natural gas (RNG), and hydrogen.
- Ideal for sites that have consistent thermal and electric loads.
- Example end users include chemical plants, pulp and paper mills, wastewater treatment facilities, food processing sites, hospitals, nursing homes, hotels, universities, correctional facilities, and multifamily buildings.



Source: https://www.energy.gov/eere/iedo/combined-heat-and-power-basics

CHP Technology Types and Electric Generation Capacities



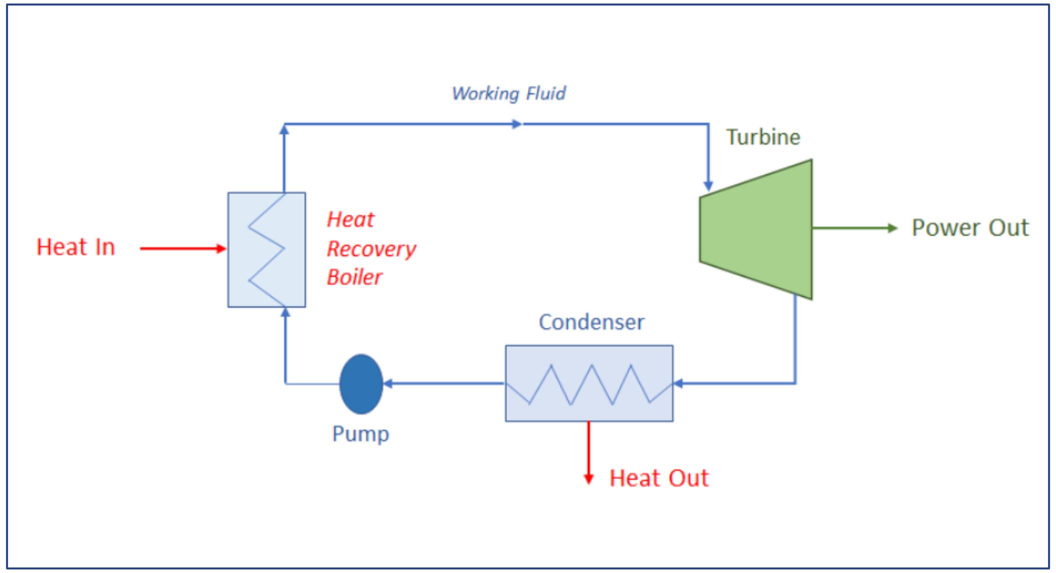
Renewable Fuels

- Fuel sources considered renewable include biodiesel, ethanol, hydrogen, biogas, renewable natural gas (RNG), and renewable diesel.
  - **Biodiesel** can be manufactured from vegetable oils, animal fats, or recycled restaurant grease for use in diesel vehicles equipment.
  - **Ethanol** is made from corn and other plant materials.
  - **Hydrogen,** when used in an onsite generator to provide electricity, is a zero emissions alternative fuel produced from diverse energy sources.
  - **Biogas** is methane-rich gas formed from anaerobic digestion at farms, wastewater treatment plants, and landfills.
  - **RNG** is essentially biogas (the gaseous product of the decomposition of organic matter) that has been processed to purity standards. RNG is a pipeline-quality gas that is fully interchangeable with conventional natural gas.
  - **Renewable diesel** is a fuel made from fats and oils, such as soybean oil or canola oil, and is processed to be chemically the same as petroleum diesel.

Source: https://www.energy.gov/eere/fuelcells/hydrogen-pipelines

Waste Heat to Power (WHP)

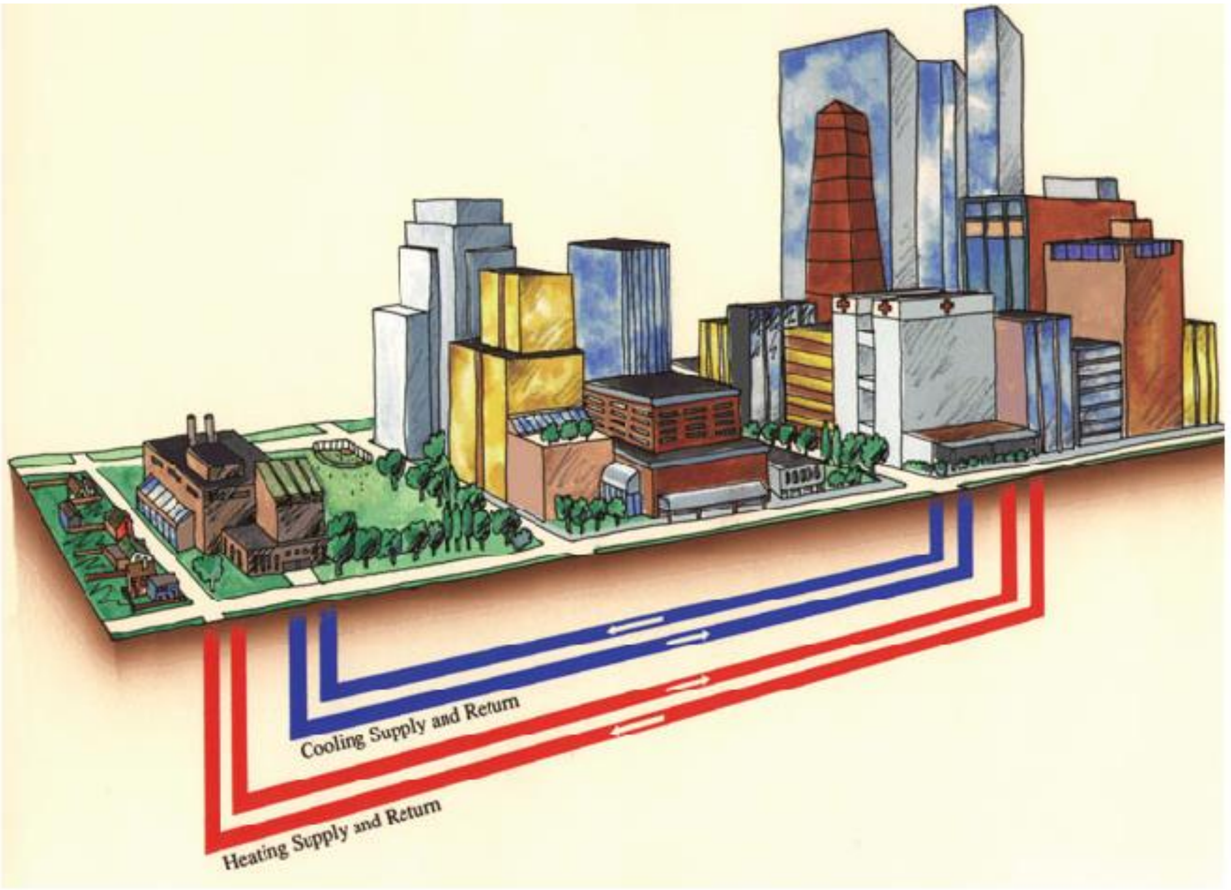
- WHP produces electricity by capturing waste heat—typically from exhaust gas or industrial processes—and converting this waste heat to electricity.
- WHP is a clean energy technology; it produces no new emissions from the use of waste heat and often displaces electricity produced from carbon-based fuels.
- In evaluating a heat recovery project, consider in order:
  - Energy Efficiency (e.g. insulation, reducing leaks, high efficiency burners, etc.)
  - Passive heat recovery strategies (recycling energy back into same process or recover energy for other on-sites uses)
  - Heat recovery by active systems (e.g. WHP)



Source:https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Waste_Heat_to_Power_Fact_Sheet.pdf

District Energy Systems

- Characterized by one or more central plants producing hot water, steam, and/or chilled water, which are distributed through a network of insulated pipes to provide hot water, space heating, and/or air conditioning for nearby buildings.
- Serve a variety of end-use markets, including downtowns, college and university campuses, hospitals and healthcare facilities, airports, military bases, and industrial complexes.
- By combining buildings and loads, district energy systems create economies of scale that enable the use of additional clean energy technologies.
- Combining a number of diverse load profiles allows the central energy plant equipment to operate at high load factors, resulting in higher levels of efficiency.



Source: www.districtenergy.org

Industrial Heat Pumps (IHPs)

- IHPs are a class of active heat-recovery equipment that enables the re-use of process energy for space heating, hot water, and other applications, by increasing the temperature of a waste-heat stream to a higher, more useful temperature.
- IHPs can facilitate energy savings when conventional passive-heat recovery is not possible. Under the right circumstances, a heat pump can reduce energy costs, particularly when:
  - the heat output is at a temperature where it can replace a purchased energy source, such as boiler steam or fuel-fired process heat
  - the cost of energy to operate the heat pump is less than the value of the energy saved.
- Most common types include closed-cycle mechanical heat pumps, open-cycle mechanical vapor compression heat pumps, open-cycle thermocompression heat pumps, and closed-cycle absorption heat pumps.

Source: https://www.aceee.org/blog-post/2023/06/new-federal-funds-can-help-companies-invest-industrial-heat-pumps

Technology-Specific Favorable Site-Attributes

	Solar Photovoltaics	Distributed Wind Turbines	Battery Energy Storage Systems	Combined Heat and Power Systems	Heat Pumps
High $/kWh Electricity Rate	Positive	Positive	Neutral	Positive	Negative
High $/kW Demand Charge Rate	Neutral	Neutral	Positive	Positive	Negative
High Nat. Gas Prices	Neutral	Neutral	Neutral	Negative	Positive
Available Roof Space	Positive	Neutral	Neutral	Neutral	Neutral
Available Land Space	Positive	Positive	Neutral	Neutral	Neutral
High Heating Loads	Neutral	Neutral	Neutral	Positive	Positive
24/7 Electricity and Heating Loads	Negative	Positive	Negative	Positive	Neutral

Positive	N Neutral	Negative

Note, the magnitude of each site attribute, the combination of two or more site attributes, and the combination technologies may have different outcomes than what is qualitatively characterized in this table as favorable, neutral, and negative criteria.

No-Cost Technical Assistance Resources Available via the Onsite Energy TAP

Getting Started: How to Work with the Midwest Onsite Energy TAP

Contact Your Regional TAP

Contact the Onsite Energy TAP in your region to start exploring onsite energy opportunities.

Discuss Site Characteristics, Goals, Objectives

Meet with the Onsite Energy TAP to discuss preliminary interest in onsite energy and learn about the facility's needs and energy-related goals.

Collect Site Data

Work with the Onsite Energy TAP to collect data needed to perform technical assistance (e.g., facility size, operations, electric and gas usage, etc.).

Conduct Analysis

Onsite Energy TAP works with technical analysis team to perform initial screenings for multi-technology options or advanced analysis to support project installations.

Review Results

When the results are ready, meet with your Onsite Energy TAP to review and discuss next steps (e.g., options worth further analysis or additional support available)

Modeling Approach to Evaluating Onsite Energy Technologies

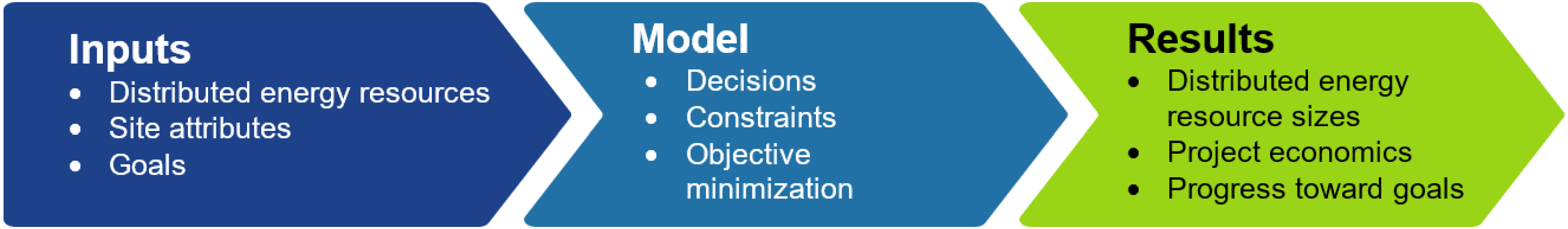


Figure 1. REopt screening analysis inputs, model considerations, and result

Minimum required:
Annual electric consumption (kWh)
Average-blended electricity price ($/kWh)
Annual natural gas consumption (million British thermal units [MMBtu])
Natural gas price ($/MMBtu)
Estimate of usable land (acres)
Estimate of usable roof area (square feet)
Optional (to strengthen the analysis):
Operating hours/schedule (e.g. two 8-hour shifts per day seven days a week)
Building type(s) and size(s) (e.g., a large office = 50,000 square feet)
State and local incentives ($ or $/kW)

$$
\begin{aligned}
\text{minimize} \quad & z^{\max} - z^{\min} \\
\text{subject to} \quad & \sum_{i \in C} x_i y_{ij} \le z^{\max} \quad \forall j \in P \\
& \sum_{i \in C} x_i y_{ij} \ge z^{\min} \quad \forall j \in P \\
& \sum_{j \in P} y_{ij} = 1 \quad \forall i \in C \\
& \sum_{i \in C} y_{ij} = n \quad \forall j \in P \\
& y_{ij} \in \{0,1\} \quad \forall i \in C, j \in P
\end{aligned}
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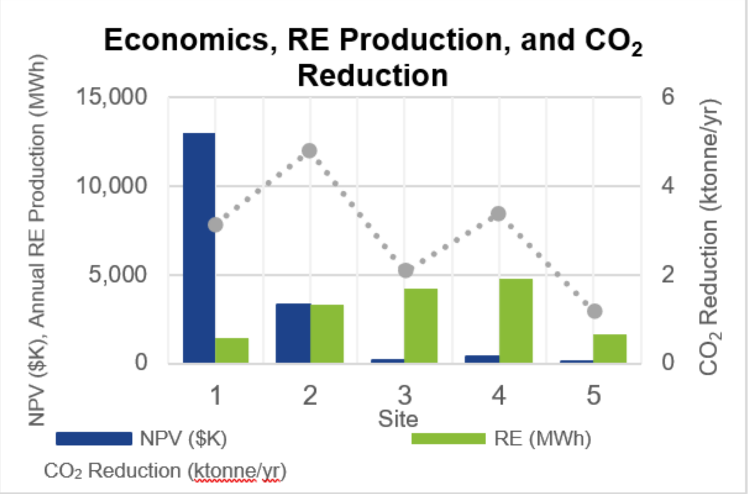
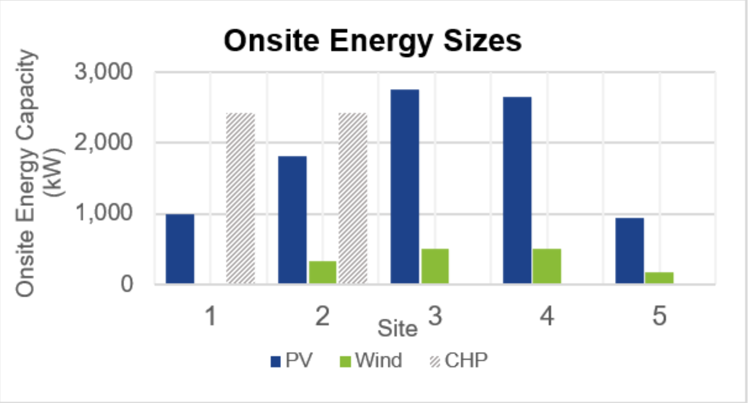




Initial Technical Assistance – Example Results

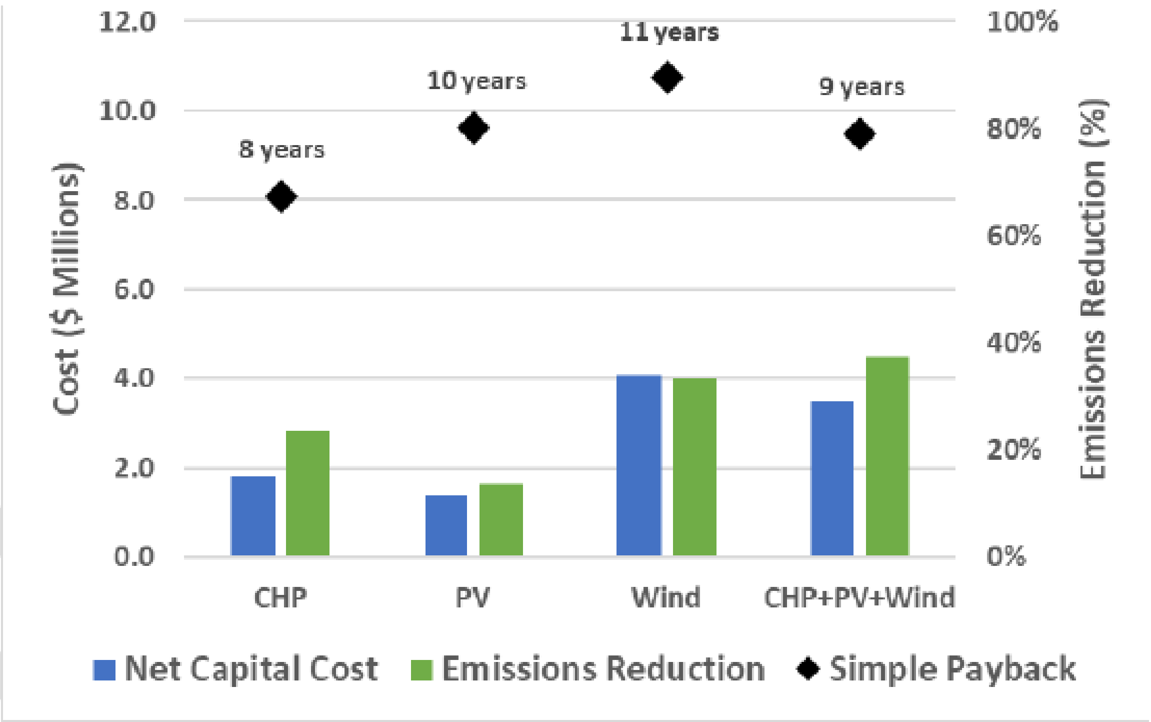
Table 1: Technology Down-selection

Technology	Analyzed for ITA	Option for ATA	Explanation
Combined Heat and Power (CHP)	Y	Y	Consistent thermal load makes CHP a viable option. Could consider alternative fuel option (landfill gas) indicated in data collection form to further reduce emissions as part of an ATA.
Solar Photovoltaic (PV)	Y	Y	Substantial roof/open parking lots area availability makes the site a strong candidate for solar PV. A more detailed PV analysis as part of an ATA could be used to further optimize system economics and performance.
Wind Turbines (Wind)	Y	Y	Land availability onsite makes wind turbine generation a viable option. A more detailed site assessment as part of an ATA could help determine ideal placement and whether trees would need to be cleared and how that would impact project economics and performance.
Battery Energy Storage System (BESS)	N	Y	Electrical load is flat, and the rate structure does not incentivize short-term load shifting. Even if there was a tariff option with high on-peak-to-off-peak price ratios, a 6+ hour duration battery would likely be needed to sufficiently shift a flat load. However, BESS could be evaluated as part of an ATA resilience scenario.
Concentrated Solar Thermal (CST)	N	Y	CST was not evaluated as part of the ITA but could be considered as an alternative to CHP as part of an ATA, especially if site emission reduction is a priority. There is sufficient undeveloped land to accommodate a significant CST system.
Geothermal Heat Pumps (GHP)	N	N	Space heating loads are negligible and do not warrant consideration of space heating solutions. GHP cannot serve facility's process heating loads.
Air Source Heat Pumps (ASHP)	N	N	Space heating loads are negligible and do not warrant consideration of space heating solutions. ASHP cannot serve facility process heating loads.
Industrial Heat Pumps (IHP)	N	N	Collected site data do not indicate the presence of a waste heat source that could be boosted by IHPs to serve process heating loads.
Hot Thermal Storage (HTS)	N	N	There is no time shift needed between CHP heat generation and the heating load, so HTS is not needed.
Chilled Thermal Storage (CTS)	N	N	CTS was not considered because there is no economic incentive for time shifting cooling load, for many of the same reasons as for BESS.

Table 2: ITA Analysis Summary

	BAU	CHP	PV	Wind	CHP+PV+Wind
Electricity Cost ($/year)	1,260,000	460,000	1,080,000	810,000	280,000
Natural Gas Cost ($/year)	450,000	880,000	450,000	450,000	880,000
Incremental O&M Cost ($/year)	-	150,000	40,000	70,000	180,000
Net Operating Cost Savings ($/year)	-	230,000	140,000	380,000	370,000
Net Capital Cost ($)	-	1,830,000	1,380,000	4,090,000	3,510,000
Simple Payback (years)	-	8	10	11	9
Site CO_2 Emissions Reduction (tonnes/year)	-	42,000	24,000	59,000	67,000
Site CO_2 Emissions Reduction (%)	-	24%	14%	33%	38%
System Size(s) (kW)	-	1,104	2,000	2,000	CHP: 1,104; PV: 2,000

BAU: Business as usual; CHP: Combined heat and power; PV: Solar photovoltaic; Wind: Wind power



Continued Technical Assistance with the Onsite Energy TAP

Screening and Preliminary Analysis

Quick screening questions with spreadsheet payback calculator; Advanced technical assistance to explore equipment or operational scenarios.

Feasibility Analysis

Perform 3rd Party reviews of site feasibility assessments: Estimates on savings, installation costs, simple paybacks, equipment sizing, and type.

Investment Grade Analysis

Perform 3rd Party reviews of Engineering Analysis. Review equipment sizing and choices.

Procurement, Operations, Maintenance, Commissioning

Review specifications and bids.

Summary

- DOE recognizes 4 key pillars to Industrial Decarbonization:

  1) energy efficiency, 2) industrial electrification, 3) LCFFES, and 4) CCUS

- Onsite Energy technology solutions can provide:

  1) improved resiliency, 2) operating with more flexibility, 3) reduced operating costs, 4) reduced emissions

- Onsite Energy TAPs can provide no-cost technical assistance services to analyzing onsite energy technology solutions

Onsite Energy Technical Assistance Partnerships

U.S. DEPARTMENT OF ENERGY

Midwest

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