Exploring Industrial Decarbonization and Overview of DOE Technical Assistance Services at UIC

ERC Speaker Series

March 23, 2023

UIC ENGINEERING

Energy Resources Center (ERC) Oveview

- **Interdisciplinary public service, research, and special projects organization** based out of UIC's College of Engineering

- **Established in 1973** as an **energy advisor** to the State of Illinois and City of Chicago, today operates as a **"fast response" team** of professionals and academia researchers

- Committed to **providing most comprehensive and up-to-date solutions** to the **energy and environmental problems** affecting industrial, commercial, institutional, and residential sectors

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Center Services and Core Research Areas

ERC Services

- Targeted Education
- Technical Assistance
- Academic Research
- Policy Analysis
- Workforce Develop-ment

ERC Current Core Research Areas

Bioenergy

Distributed Energy & Renewables

Energy Efficiency

Policy & Utility Data Analytics

Clean Transportation

Sustainable Landscapes

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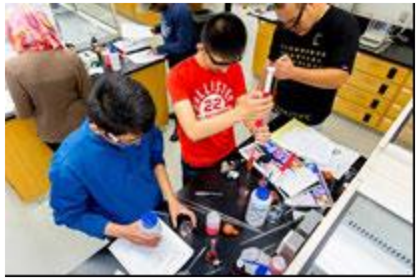
2023 ERC Speaker Series Monthly Topics

- Thursday, February 23 – Economic, Ecological, and Performance Research of Co-Located Pollinator Plants at Photovoltaic Sites
- **Thursday, March 23 – Exploring Industrial Decarbonization**
- **Thursday, April 27 – Energy Efficiency**
- **Thursday, May 25 – Microgrids and Energy Resiliency**
- **Thursday, June 22 – New Research on Cancer Reduction from Biofuels in Transportation & Aviation**
- **Thursday, July 27 – Anaerobic Digestion**
- **Thursday, August 24 - STEM Education**
- **Thursday, September 28 – Pollinators and Pollinator Habitats**
- **Thursday, October 26 – Decarbonizing with CHP: From Natural Gas to Zero Carbon Fuels**



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Featured Topic and Presenters

Title: Exploring Industrial Decarbonization and Overview of DOE Technical Assistance Services at UIC

Agenda:

1. Exploring Industrial Decarbonization *with the US DOE Industrial Decarbonization Roadmap*
2. Energy Efficiency *with the US DOE Industrial Assessment Center (DOE IAC)*
3. Onsite CHP *with the US DOE Midwest-Central Combined Heat and Power Technical Assistance Partnerships (DOE CHP TAPs)*
4. Q&A

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Industrial Decarbonization

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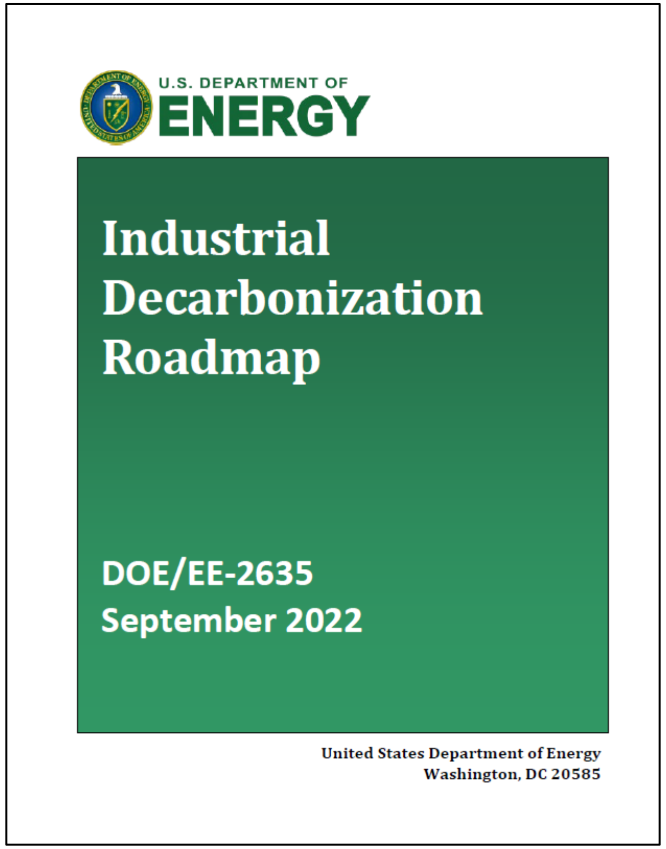
U.S. DOE "Industrial Decarbonization Roadmap"


U.S. DEPARTMENT OF ENERGY

Industrial Decarbonization Roadmap

DOE/EE-2635
September 2022

United States Department of Energy
Washington, DC 20585

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

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U.S. Primary Energy-Related CO2 Emissions by End Use Sector and Breakout by Industrial Subsector

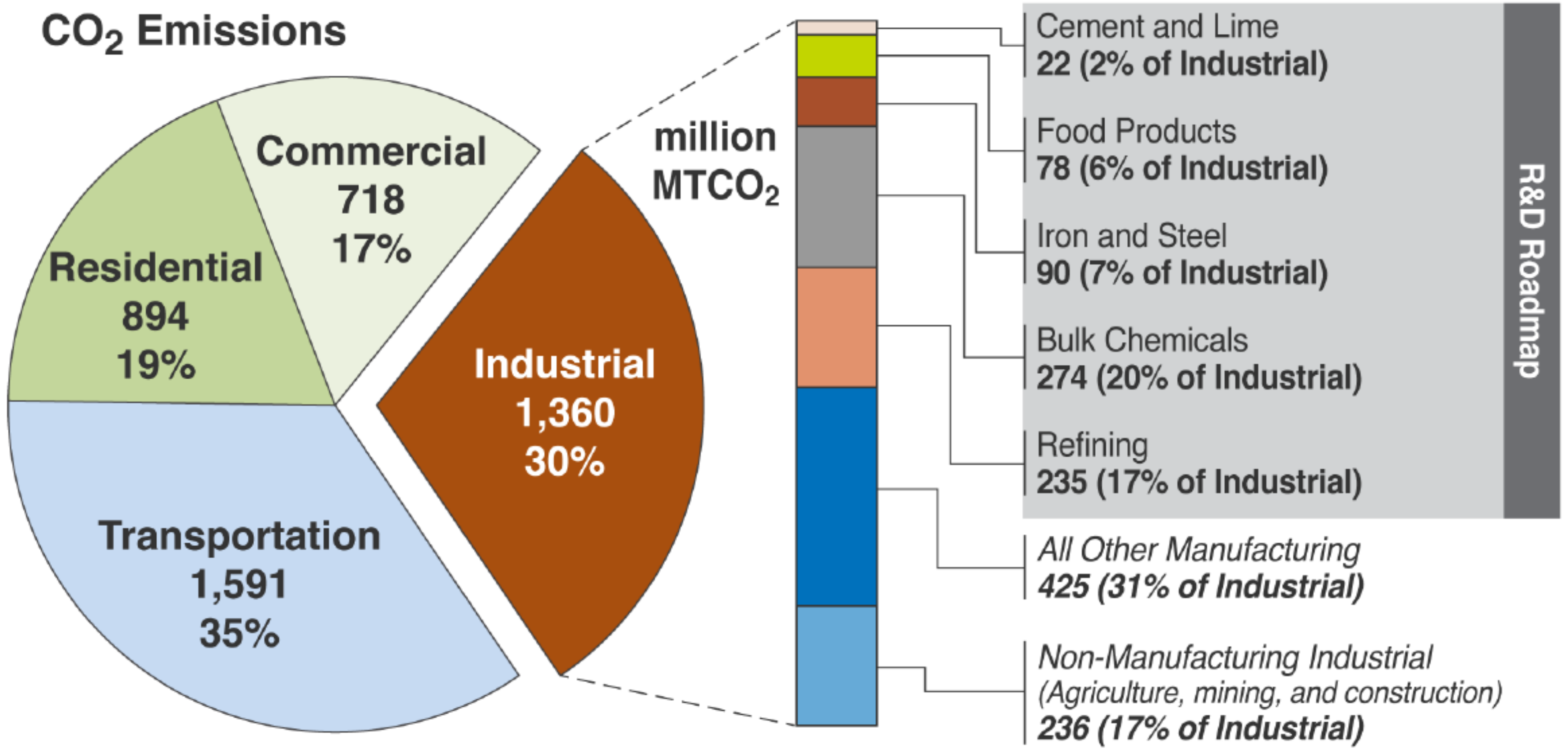

FIGURE 3. U.S. PRIMARY ENERGY-RELATED CO_2 EMISSIONS BY END USE SECTOR (LEFT PIE CHART) AND A BREAKOUT BY INDUSTRIAL SUBSECTOR (RIGHT STACKED CHART) IN 2020.

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

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Distribution of Process Heat Temperature Ranges by Industrial Subsector

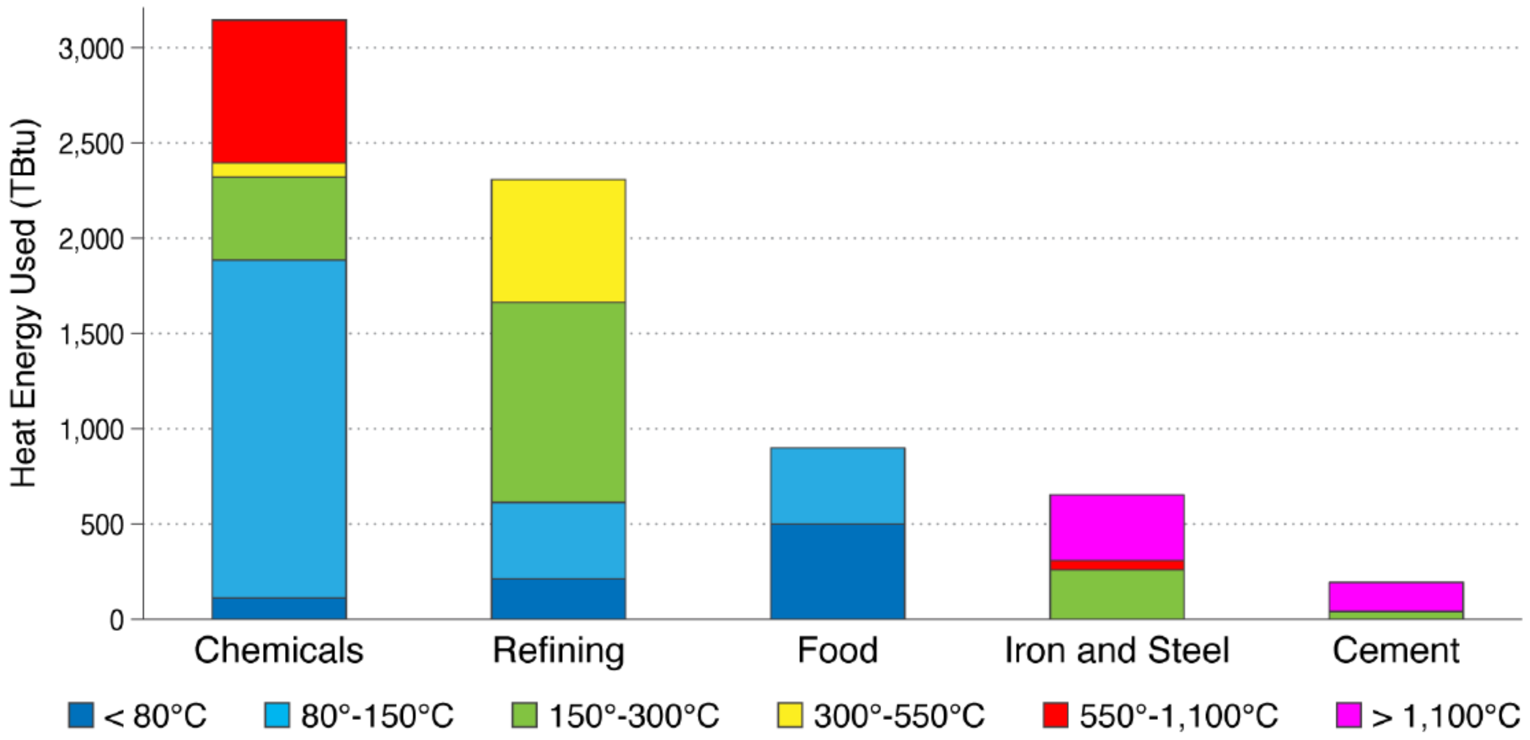

FIGURE 6. DISTRIBUTION OF PROCESS HEAT TEMPERATURE RANGES BY INDUSTRIAL SUBSECTOR IN 2014.

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

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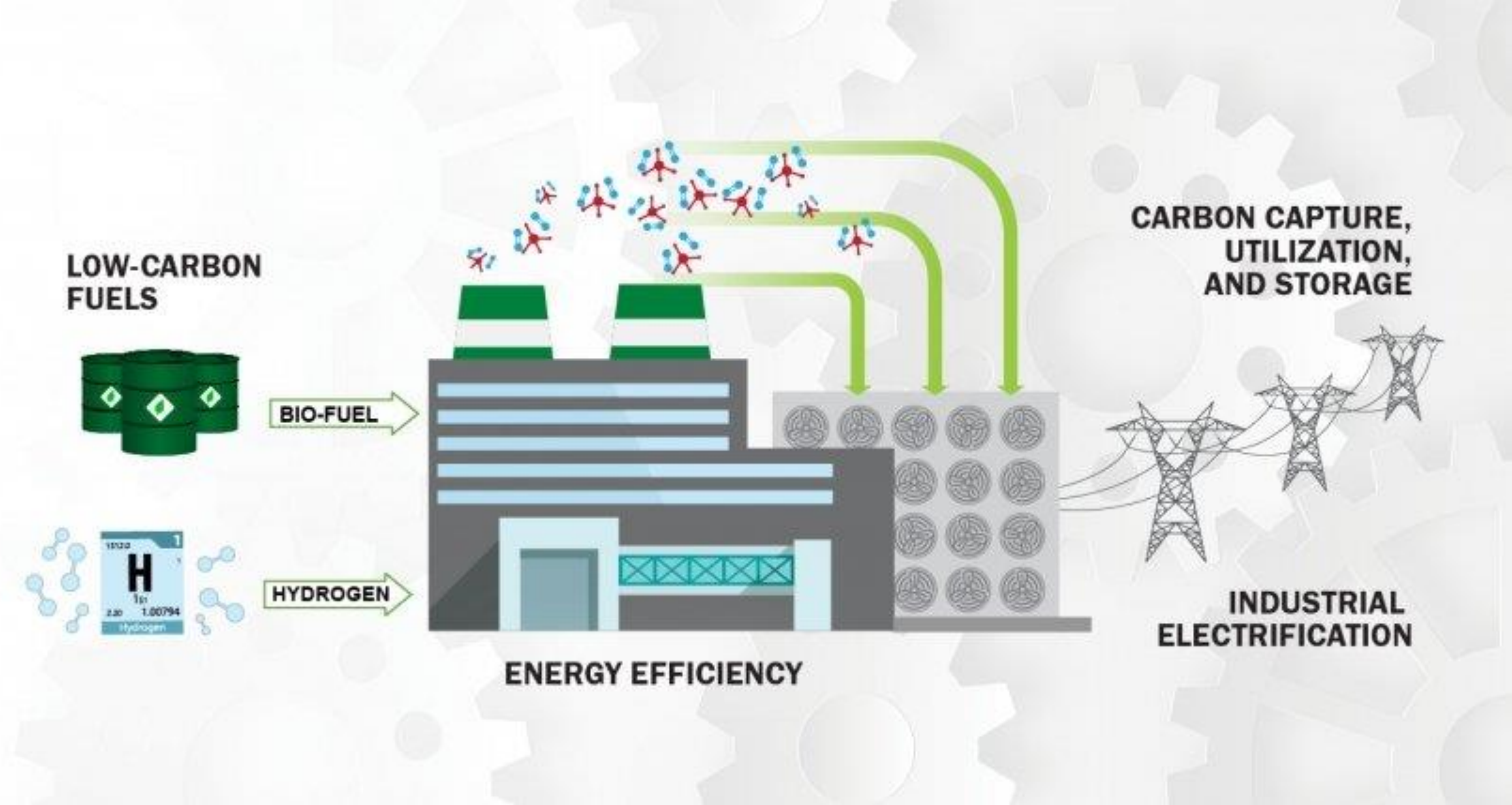
Strategies for Decarbonizing U.S. Industries

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

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

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Path to Net-Zero Industrial CO2 Emissions in U.S. for 5 Carbon-Intensive Industrial Subsectors

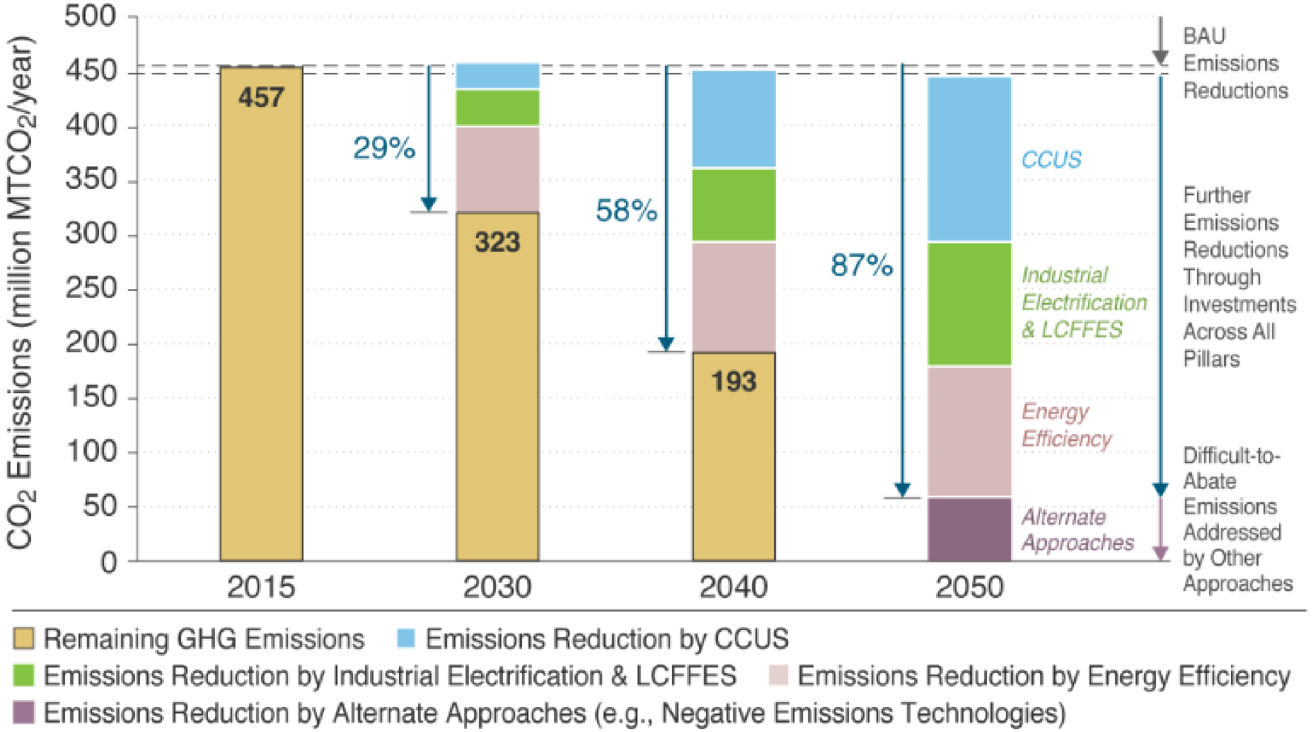

FIGURE ES 1. THE PATH TO NET-ZERO INDUSTRIAL CO_2 EMISSIONS IN THE UNITED STATES FOR FIVE CARBON-INTENSIVE INDUSTRIAL SUBSECTORS, WITH CONTRIBUTIONS FROM EACH DECARBONIZATION PILLAR: ENERGY EFFICIENCY; INDUSTRIAL ELECTRIFICATION; LOW-CARBON FUELS, FEEDSTOCKS, AND ENERGY SOURCES (LCFFES); AND CARBON CAPTURE,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

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

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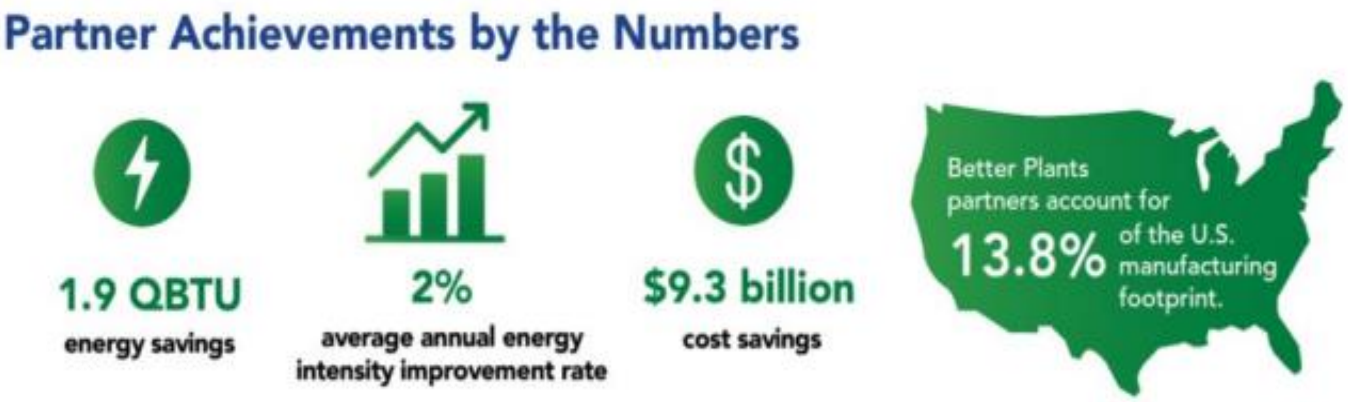
Energy Efficiency

- Offers greatest opportunities for near-term decarbonization
- DOE Better Plants Program
- Over 250 Better Plants partners achieving 116 M metric tons of CO2 saved
- Goal of reducing energy intensity by 25% over a 10-year period across all U.S



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

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Energy Efficiency Examples

- Switching to VFDs for motors of pumps, fans etc
- Efficient use of compressed air
- Smart manufacturing and advanced data analytics
- Combined Heat and Power (CHP)

www.powermag.com

www.grainger.com

www.variablefrequencydrive.net

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

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Industrial Electrification

- Over 50% of all manufacturing energy used for thermal processing (only 5 % electrified)
- Industrial Electrification aims to:
    - Improve the energy efficiency of existing technologies
    - Innovate new electric or hybrid systems
    - Overcoming economic and technical barriers to implementing electro-technologies in existing fossil-based processing systems
- Examples include electrification of high-temperature range processes such as those found in iron, steel, and cement making, electrification of hydrogen production for industrial process use, replacing thermally-driven processes with electrochemical ones and electrification of process heat using induction, radiative heating, or advanced heat pumps

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

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Industrial Electrification (Example)

Mechanical vapor recompressor

Industrial Heat Pump Technology

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

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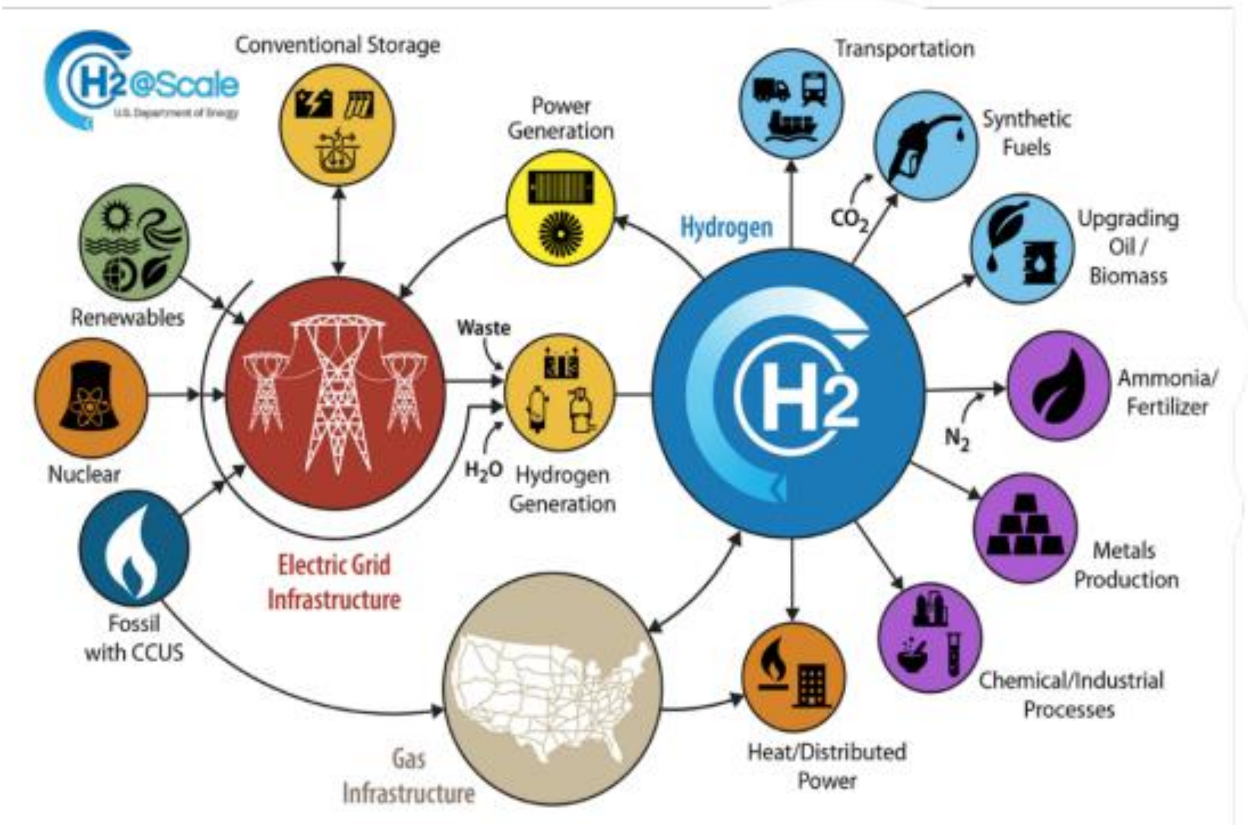
Low-Carbon Fuels, Feedstocks, and Energy Sources (LCFFES)

- Some technologies are advanced enough
- Others require RD&D
- For clean Hydrogen, cost goal is $1/kg
- DOE H2@Scale initiative
- Example: Using clean hydrogen to reduce iron ore



DOE's H2@Scale Opportunities[14]

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

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

- Fuel-flexible processes (Hydrogen and NG engines)
- The use of biofuels and biofeedstocks (Ethanol)
- On-site renewable energy generation, especially solar power

www.cummins.com

www.firstcry.com

www.goldenagri.com

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

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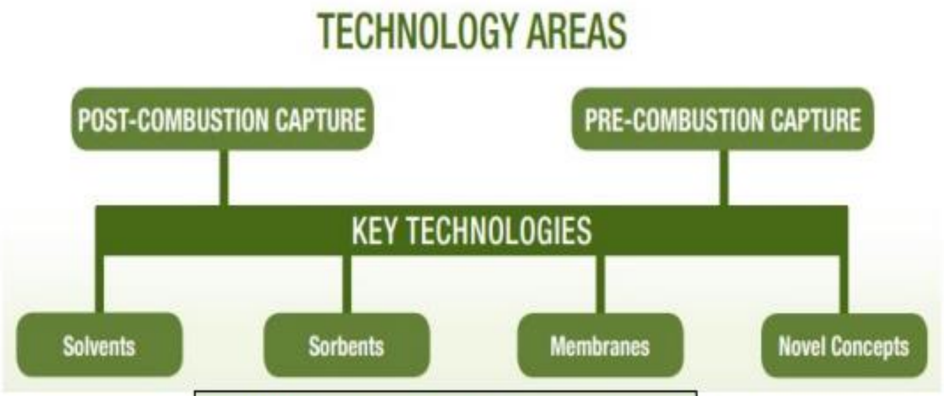
Carbon Capture, Utilization, and Storage (CCUS)

- The first 3 approaches can only reduce around 40% targeted emissions
- CCUS key to reach net-zero emissions
- CCUS predicted to be the largest source of long-term emission reductions
- Key to be implemented in industries where CO_2 emissions are non-energy related such as cement industry
- Examples:
  - Post-combustion chemical absorption of CO_2
  - Construction of CO_2 pipelines and other CCUS-supportive infrastructure



CCUS Technology Approaches

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

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Carbon Capture, Utilization, and Storage (CCUS) Technologies

Categories of CO_2 Capture Technologies:

1. Chemical Absorption – Aker Carbon Capture - https://www.akercarboncapture.com/
2. Physical Separation – Fresme http://www.fresme.eu/
3. Oxy-fuel Separation – Canmet Energy's 2G technology from Parametric Solutions https://psnet.com/
4. Membrane Separation – Climeworks https://climeworks.com/net-zero-solutions-for-businesses
5. Chemical Looping – Demo Clock https://www.sintef.no/globalassets/project/democlock/pdf/eu-democlock-brochure.pdf
6. Bioenergy Carbon Capture & Storage - Pond Tech www.pondtech.com

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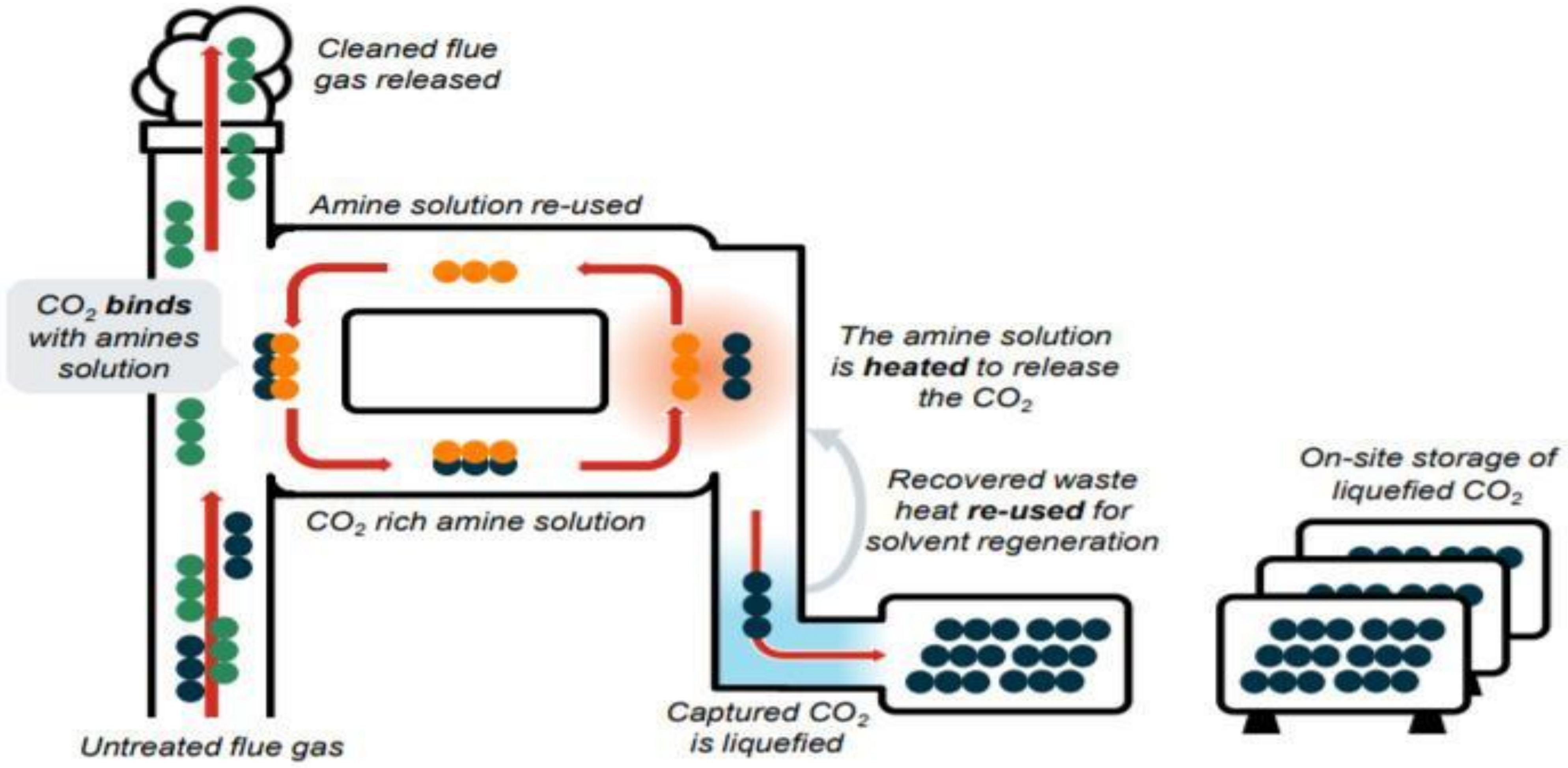
CCUS Chemical Absorption Example



Source: https://www.akercarboncapture.com/

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

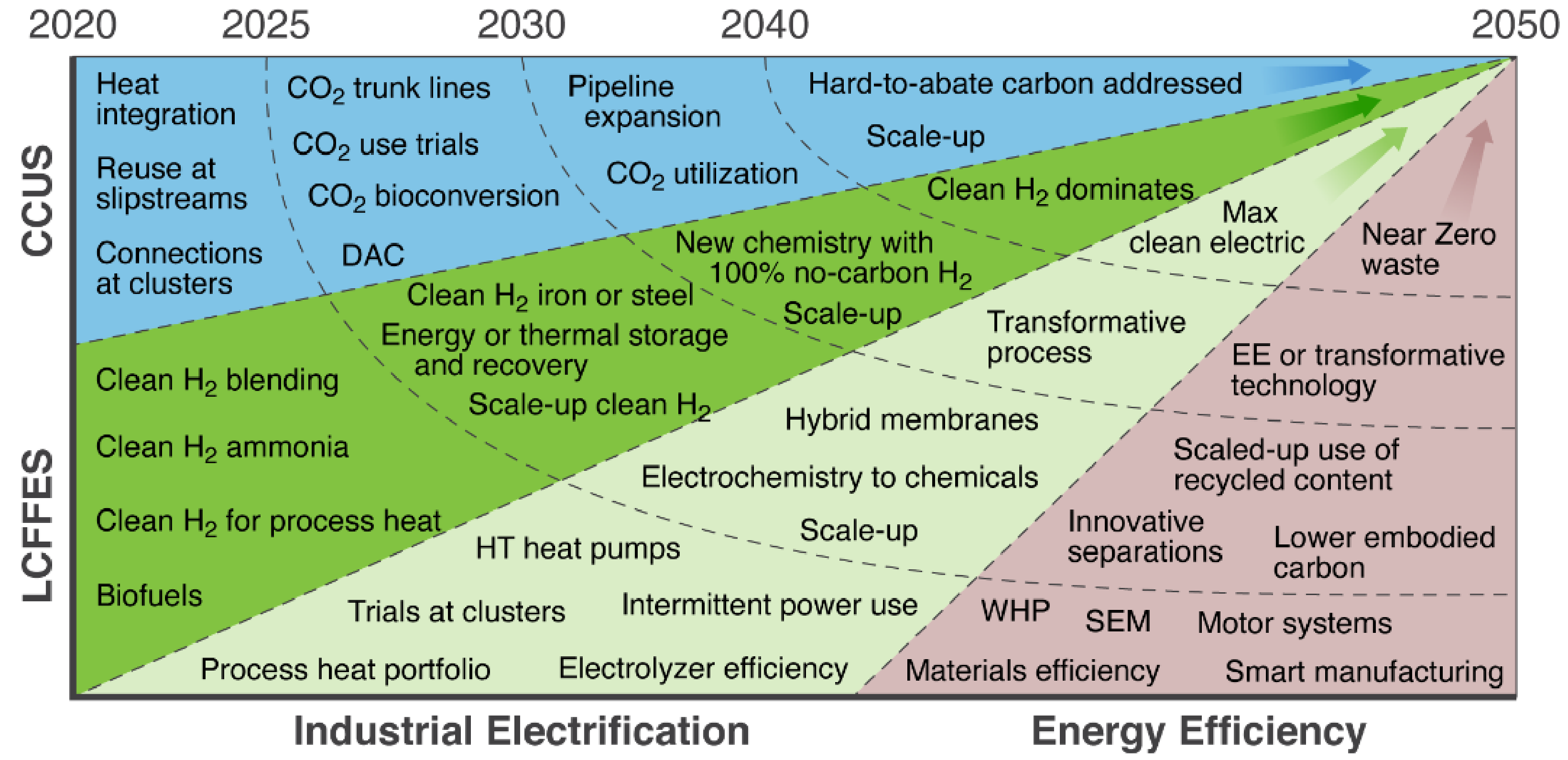

FIGURE 10. LANDSCAPE OF MAJOR RD&D INVESTMENT OPPORTUNITIES FOR INDUSTRIAL DECARBONIZATION ACROSS ALL SUBSECTORS BY DECADE AND DECARBONIZATION PILLAR.

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

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Landscape of DOE Office Activities Across the Four (4) Decarbonization Pillars to Achieve Net-Zero Emissions by 2050

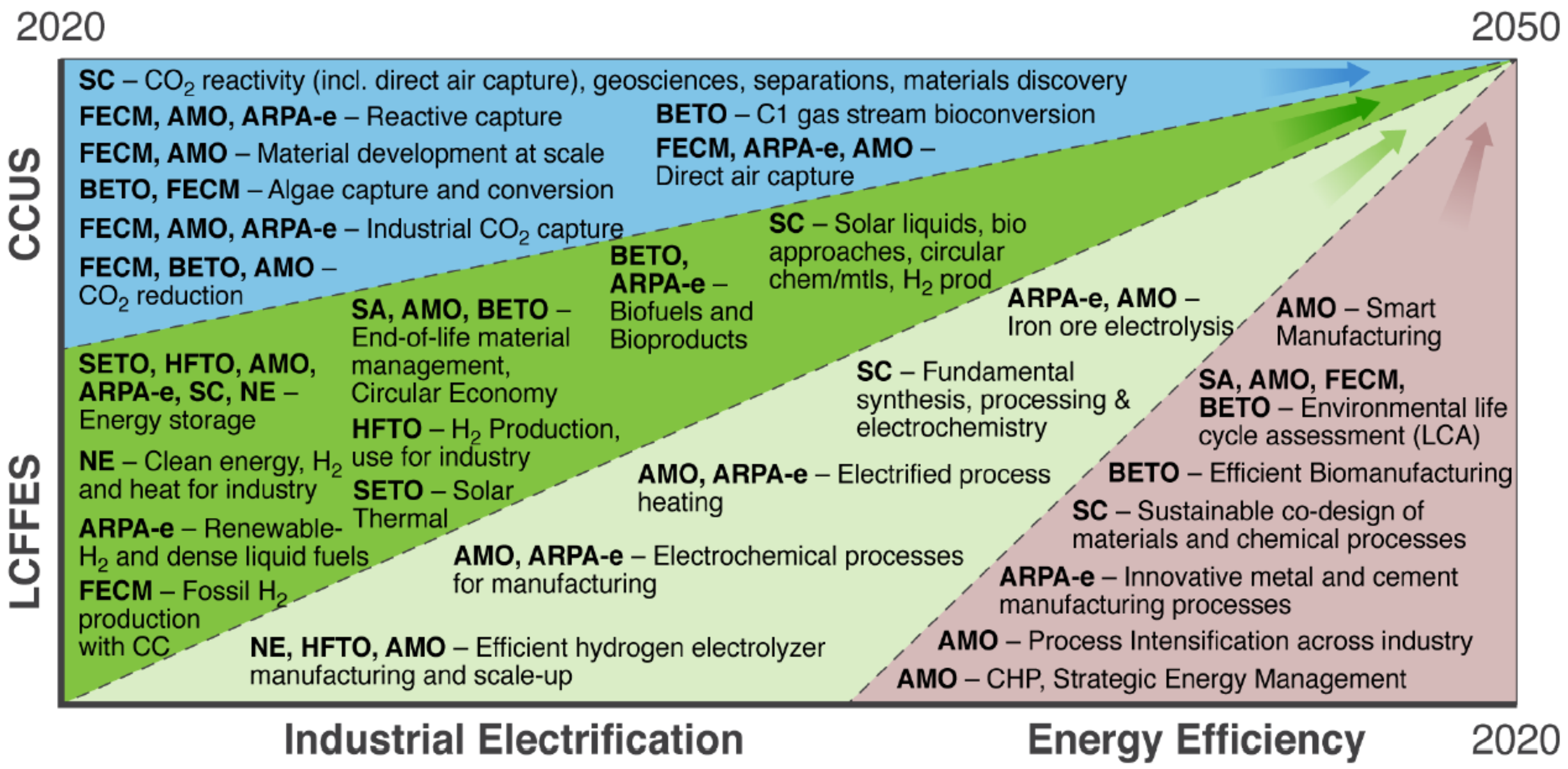

FIGURE 59. LANDSCAPE OF DOE OFFICE ACTIVITIES ACROSS THE FOUR DECARBONIZATION PILLARS TO ACHIEVE NET-ZERO EMISSIONS BY 2050.

AMO: ADVANCED MANUFACTURING OFFICE; ARPA-E: ADVANCED RESEARCH PROJECTS AGENCY – ENERGY; BETO: BIOENERGY TECHNOLOGIES OFFICE; FECM: OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT; HFTO: HYDROGEN AND FUEL CELL TECHNOLOGIES OFFICE; NE: OFFICE OF NUCLEAR ENERGY; SA: EERE STRATEGY ANALYSIS; SC: OFFICE OF SCIENCE; SETO: SOLAR ENERGY TECHNOLOGIES OFFICE.

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

UIC's No-Cost Technical Assistance Resource Programs

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US Department of Energy Industrial Assessment Centers (IACs)

- Established by the US Department of Energy in 1976
- One of the US DOE’s longest ongoing programs
- Serves small and medium sized US manufacturers and medium to large wastewater treatment plants nationwide
- Teams of university-based faculty and student engineers (trained 3,300+ students to date)

Industrial Assessment Center
U.S. DEPARTMENT OF ENERGY

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The US Department of Energy Industrial Assessment Centers (IACs) Goals

Three main goals of the IAC Program:

1. Assessments – Provide no-cost in-depth evaluations of a facility which will include baseline energy analysis, a walkthrough of the facility, and a full list of identified measures including savings, possible incentive funding, and economic analysis

2. Workforce Development – IACs are used to train the next-generation of energy savvy engineers, more than 60% of which pursue energy-related careers upon graduation.

3. Research – Conduct research on cutting edge technologies to constantly refine the assessment process and identify new potential methods of cost effective energy reduction.

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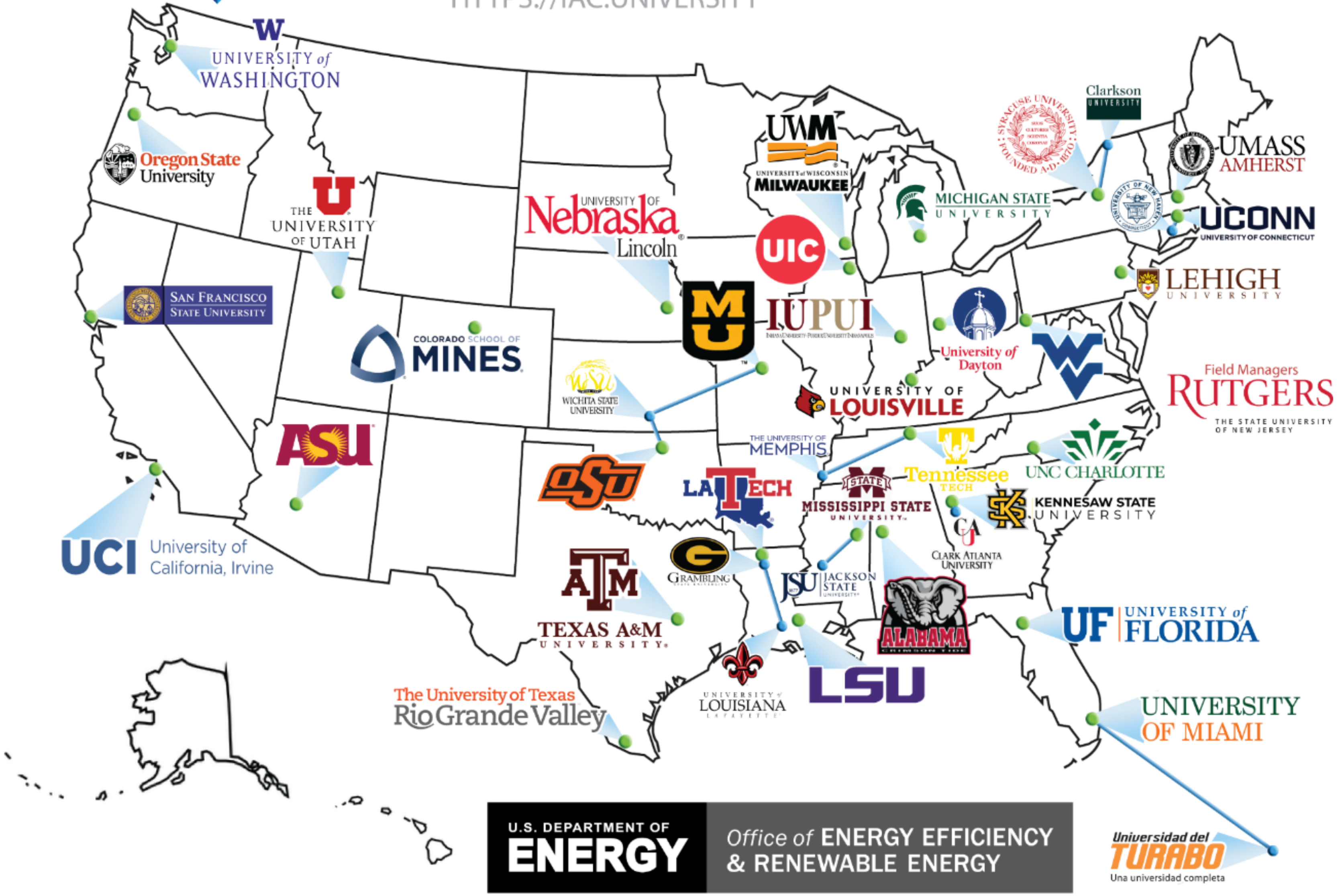
Industrial Assessment Centers 2022-2026

HTTPS://IAC.UNIVERSITY



The IAC program has already conducted over 20,475 assessments with more than 153,108 associated recommendations. Average recommended yearly savings is $138,295 (as of 3/15/23).

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IAC Covers All Manufacturing Sectors

IAC Assessments cover ALL manufacturing sectors

NAICS		Asmts
311	Food Manufacturing	1084
312	Beverage and Tobacco Product Manufacturing	249
313	Textile Mills	118
314	Textile Product Mills	64
315	Apparel Manufacturing	50
316	Leather and Allied Product Manufacturing	9
321	Wood Product Manufacturing	409
322	Paper Manufacturing	349
323	Printing and Related Support Activities	229
324	Petroleum and Coal Products Manufacturing	107

NAICS		Asmts
322	Paper Manufacturing	349
323	Printing and Related Support Activities	229
324	Petroleum and Coal Products Manufacturing	107
325	Chemical Manufacturing	617
326	Plastics and Rubber Products Manufacturing	905
327	Nonmetallic Mineral Product Manufacturing	323
331	Primary Metal Manufacturing	505
332	Fabricated Metal Product Manufacturing	1209
333	Machinery Manufacturing	728
334	Computer and Electronic Product Manufacturing	330

NAICS		Asmts
332	Fabricated Metal Product Manufacturing	1209
333	Machinery Manufacturing	728
334	Computer and Electronic Product Manufacturing	330
335	Electrical Equipment, Appliance, and Component Manufacturing	241
336	Transportation Equipment Manufacturing	767
337	Furniture and Related Product Manufacturing	212
339	Miscellaneous Manufacturing	299

Source: https://iac.university/

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IAC Eligibility Requirements

- Within Standard Industrial Codes (SIC) 20-39
- Located less than 150 miles of a participating university
- Gross annual (site) sales below $100 million
- Fewer than 500 employees at the plant site
- Annual energy bills more than $100,000 and less than $3.5 million
- No professional in-house staff to perform assessments

Eligibility for Water and Wastewater Treatment Facilities

- Water treatment plant >5 MGD
- Wastewater treatment plant >2 MGD
- Annual energy bills between $250,000 and $3.5 million

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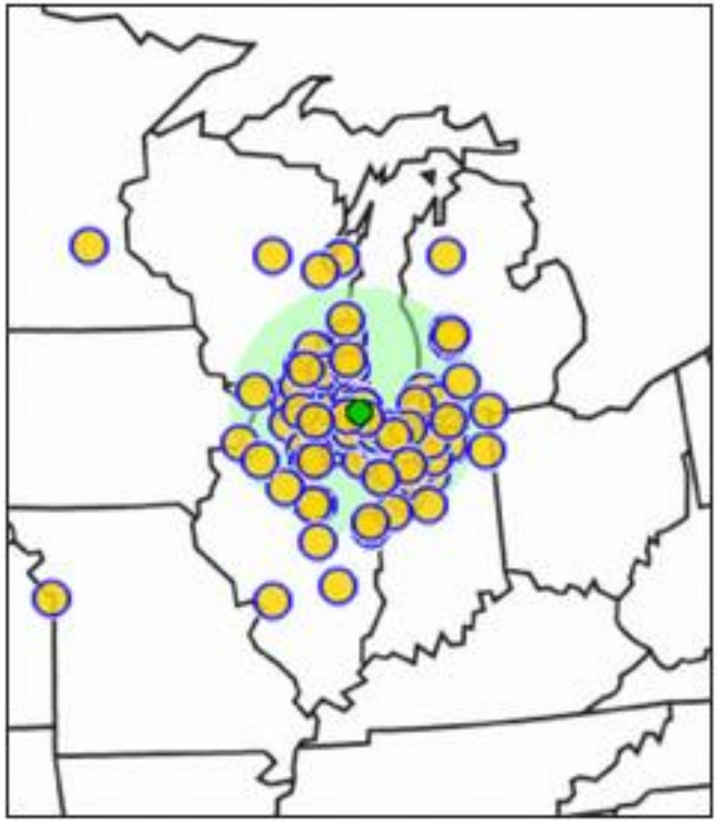
IAC Impact: Recommendations and Implementation



274 Assessments

2,133 Recommendations

3.14 Tbtu Energy Saving*

$51.43 million Cost Savings*

145 **Students Trained**

Recommended Savings

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Assessment Overview, Procedure, and Timeline

After a facility applies and is approved for an IAC assessment, the IAC will request records of 12 months of utility bills for analysis.

During the assessment, the IAC team will meet with the client, tour the facility, search for energy and environmental savings opportunities, and discuss initial findings with client.

About 6-9 months after the report is delivered, the IAC will follow up with an implementation survey to help measure the success of the IAC assessment the effectiveness of the measures.

During the pre-assessment (e.g. zoom meeting 3-5 business prior to the assessment), the IAC team will present information on the facility’s energy usage and interview the client on goals, needs, processes, and equipment.

The IAC team will use information collected on the site visit to formulate a report with recommendations for savings opportunities. A report will be delivered within 2 months of the site visit.

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IAC Site Visit Overview

Duration	Activities
30 min.	• Kick-Off Meeting
1–2 hours	• Plant Tour • Initial Data Collection
1 hour	• Tour Recap Discussion • Strategy Meeting
1–2 hours	• Additional Data Collection • Begin Analysis
30 min.	• Wrap-Up Meeting with Client

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IAC Assessment Overview: Site Visits

Site Visit Focus

- Steam / Hot Water Systems (Boilers, Steam Traps)
- Compressed Air Systems (Compressors, Air Leaks, Storage, End Uses
- Process Heating / Process Cooling (Ovens, Chillers, Cooling Towers)
- Large Motors and Pumps
- HVAC Equipment
- Lighting
- Other Process Equipment
- Cybersecurity

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IAC Assessment Overview: Report

Report Highlights

- Client will be delivered a detailed report within 60 days of the site visit
- Includes full utility analysis, electric / natural gas usage profiles, and equipment list found in pre-assessment report
- Recommendations on energy efficiency, waste reduction, and productivity improvement, including cost savings and economics
- The report will include information on utility incentive programs where applicable to make sure the client is aware of them
- All reports are confidential

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IAC Assessment Overview: Follow-Up

- The client will always be offered a follow up meeting after delivery to discuss the report findings and answer any questions
- In 6 to 9 months, the IAC will follow up with a phone call to see if the company has implemented or initiated plans to implement any of the recommended measures

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IAC Example Assessment

IAC Center	University of Illinois, Chicago
Assessment Year	2018
Principal Product	Rubber Hose Manufacturing
NAICS	**326299** - All Other Rubber Product Manufacturing
SIC	**3061** - Mechanical Rubber Goods
Sales	$100,000,000-$500,000,000
# of Employees	550
Plant Area (Sq.Ft.)	250,000
Annual Production	9,960 *Tons*
Production Hrs. Annual	8,760
Location (State)	MI

Source	Yearly Cost	Usage	Unit	Unit Cost
Electricity Usage	$876,317	13,903,105	kWh	$0.06
Electricity Demand	$12,320	2,504	kW-months/year	$4.92
Natural Gas	$421,797	100,986	MMBtu	$4.18
TOTAL ENERGY COSTS	**$1,607,291**			
RECOMMENDED SAVINGS*	**$430,333**	*Non-energy impacts included in savings. See recommendations below		
IMPLEMENTED SAVINGS*	**$430,333**			

Source: https://iac.university/assessment/

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IAC Example Assessment (cont.)

#|Description	Savings / Cost	Status	Electricity Usage $	Electricity Usage kWh	Electricity Demand $	Electricity Demand kW-months/year	Natural Gas $	Natural Gas MMBtu	Water Usage $	Water Usage Tgal	Water Disposal $	Water Disposal Tgal
01: 2.2414 USE WASTE HEAT FROM HOT FLUE GASES TO PREHEAT	$71,958 / $100,000	✓	-	-	-	-	$71,958	17,215	-	-	-	-
02: 3.3111 ADJUST PH FOR NEUTRALIZATION	$132,488 / $180,000	✓	-	-	-	-	-	-	$32,284	31,363	$100,204	31,363
03: 2.1224 REPLACE BOILER	$97,199 / $211,342	✓	-	-	-	-	$97,199	23,253	-	-	-	-
04: 3.4156 USE FLOW CONTROL VALVES ON EQUIPMENT TO OPTIMIZE WATER USE	$71,357 / $8,712	✓	-	-	-	-	-	-	$17,388	16,892	$53,969	16,892
05: 2.6218 TURN OFF EQUIPMENT WHEN NOT IN USE	$21,223 / -	✓	$21,223	303,191	-	-	-	-	-	-	-	-
06: 2.4133 USE MOST EFFICIENT TYPE OF ELECTRIC MOTORS	$36,108 / $187,206	✓	$22,116	315,934	$13,992	2,844	-	-	-	-	-	-
TOTAL RECOMMENDED	$430,333 / $687,260		$43,339	619,125	$13,992	2,844	$169,157	40,468	$49,672	48,255	$154,173	48,255
TOTAL IMPLEMENTED	$430,333 / $687,260		$43,339	619,125	$13,992	2,844	$169,157	40,468	$49,672	48,255	$154,173	48,255
	Savings / Cost		$	kWh	$	kW-months/year	$	MMBtu	$	Tgal	$	Tgal
			Electricity Usage		Electricity Demand		Natural Gas		Water Usage		Water Disposal	

Source: https://iac.university/assessment/

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IAC Teams

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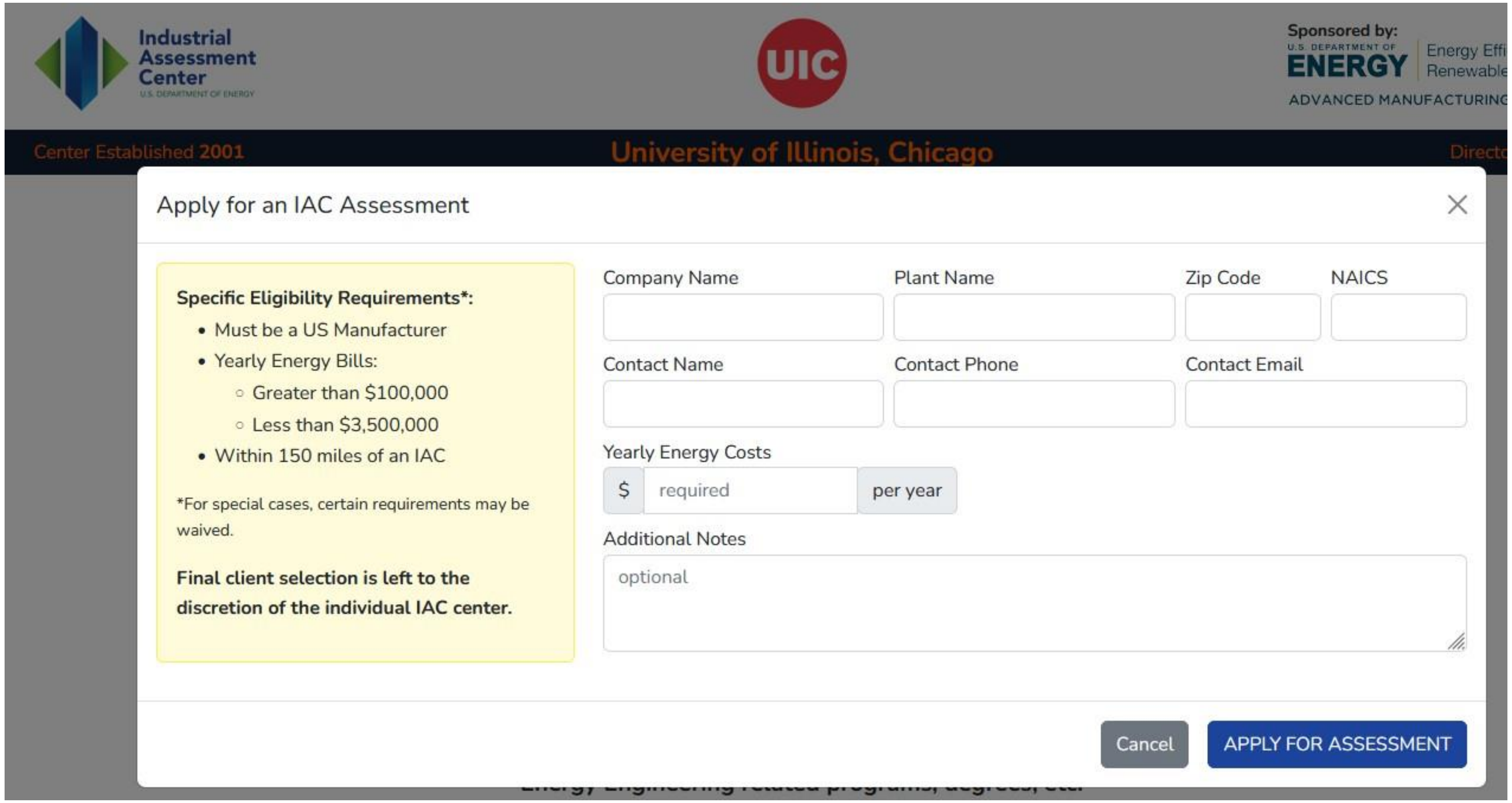
IAC Assessment: How to Apply?



Apply at the website:
https://iac.university/

or reach out directly to:

Cliff Haefke

chaefk1@uic.edu

or

Faaran Bangash

fbanga2@uic.edu

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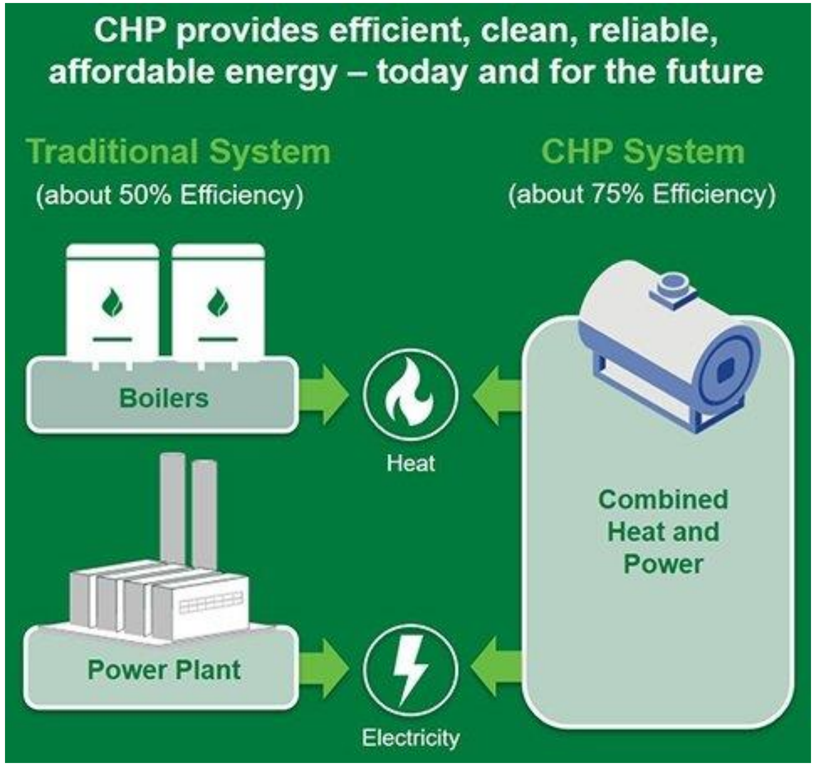
UIC's DOE Combined Heat and Power Technical Assistance Partnership (CHP TAP) Program

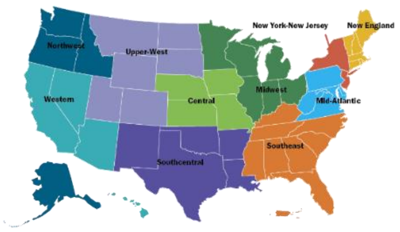
DOE's CHP Technical Assistance Partnerships (CHP TAPs) promote and assist in transforming the market for CHP, waste heat to power, and district energy technologies/ concepts throughout the United States. Key services of the CHP TAPs include:

- **End User Engagements**
  Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness. CHP TAPs offer fact-based, non-biased engineering support to manufacturing, commercial, institutional and federal facilities and campuses.

- **Stakeholder Engagements**
  Engage with strategic Stakeholders, including regulators, utilities, and policy makers, to identify and reduce the barriers to using CHP to advance regional efficiency, promote energy independence and enhance the nation's resilient grid. CHP TAPs provide fact-based, non-biased education to advance sound CHP programs and policies.

- **Technical Services**
  As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.





To learn more about the no-cost services of the 10 regional CHP TAPs, visit www.energy.gov/chptap

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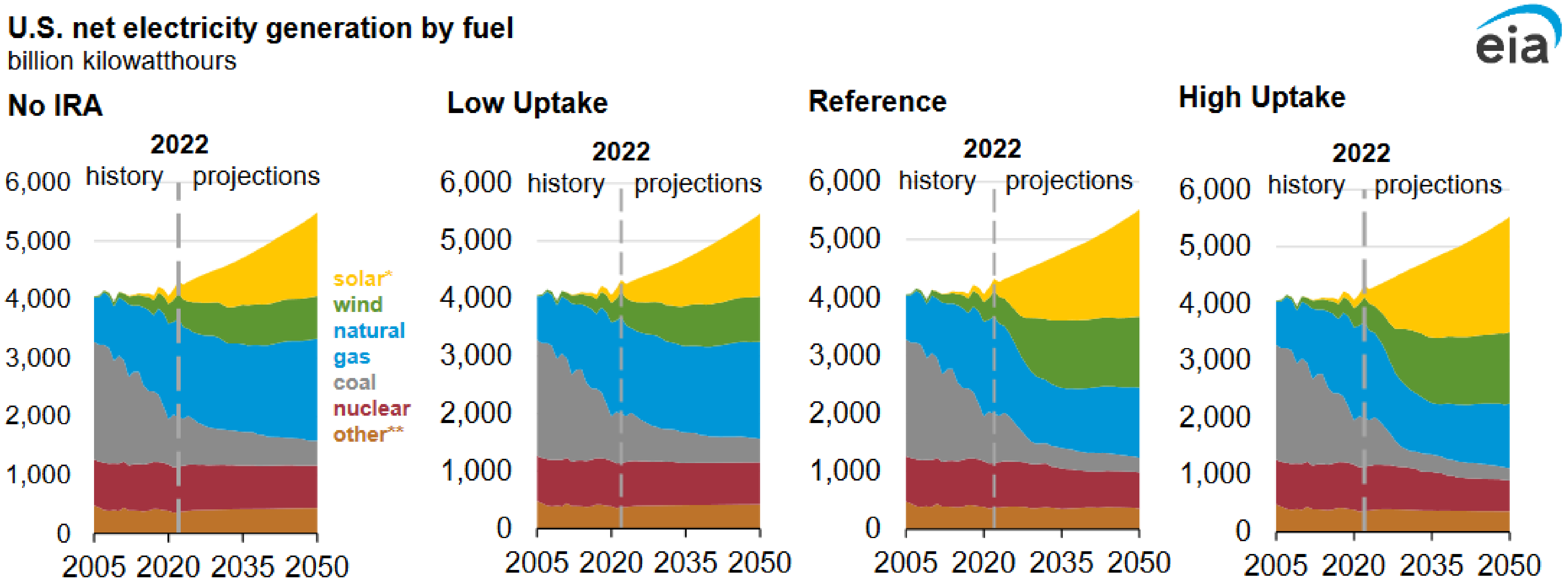
U.S. Net Electricity Generation by Fuel Type



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: IRA=Inflation Reduction Act
*Includes utility-scale and end-use photovoltaic generation and excludes off-grid photovoltaics.
**Includes petroleum, conventional hydroelectric power, geothermal, wood and other biomass, pumped storage, non-biogenic municipal waste in the electric power sector, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Source: https://www.eia.gov/outlooks/aeo/

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CHP's High Efficiency Saves CO2 Emissions Today

- CHP and renewables **displace marginal grid generation (including T&D losses)**
- Marginal generation is **currently a mix of coal and natural gas** in most regions of the US
- **CHP's high efficiency and high annual capacity factor** currently results in significant annual energy and emissions savings
- CHP's efficiency **advantages will continue as the gas infrastructure decarbonizes**

"Because emissions are cumulative and because we have a limited amount of time to reduce them, carbon reductions now have more value than carbon reductions in the future"

Source: "Time Value of Money", Larry Stein, Carbon Leadership Forum, April 2020

Category	Natural Gas CHP	Utility Solar PV	Utility Wind	Biogas CHP
Capacity, MW	20.0	43.3	30.7	20.0
Annual Capacity Factor	90%	24.3%	34.3%	90%
Annual Electricity, MWh	157,680	92,096	92,096	157,680
Annual Thermal Provided, MWh_{th}	169,466	None	None	169,466
Annual Energy Savings, MMBtu	689,110	863,954	863,954	689,110
Annual CO_2 Savings, Tons	71,375	71,375	71,375	164,448
Annual NOx Savings, Tons	59.8	39.1	39.1	59.8

Savings based on EPA AVERT Uniform EE Emissions Factors as a first level estimate of displaced marginal generation (https://www.epa.gov/avert)

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Questions ???

UIC ENERGY RESOURCES CENTER

Thank You

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