



Pathways for U.S. Industrial Transformations: Unlocking American Innovation

Dr. Avi Shultz

Director, Industrial Efficiency and Decarbonization Office

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Decarbonizing Industry is an Opportunity for America's Economy

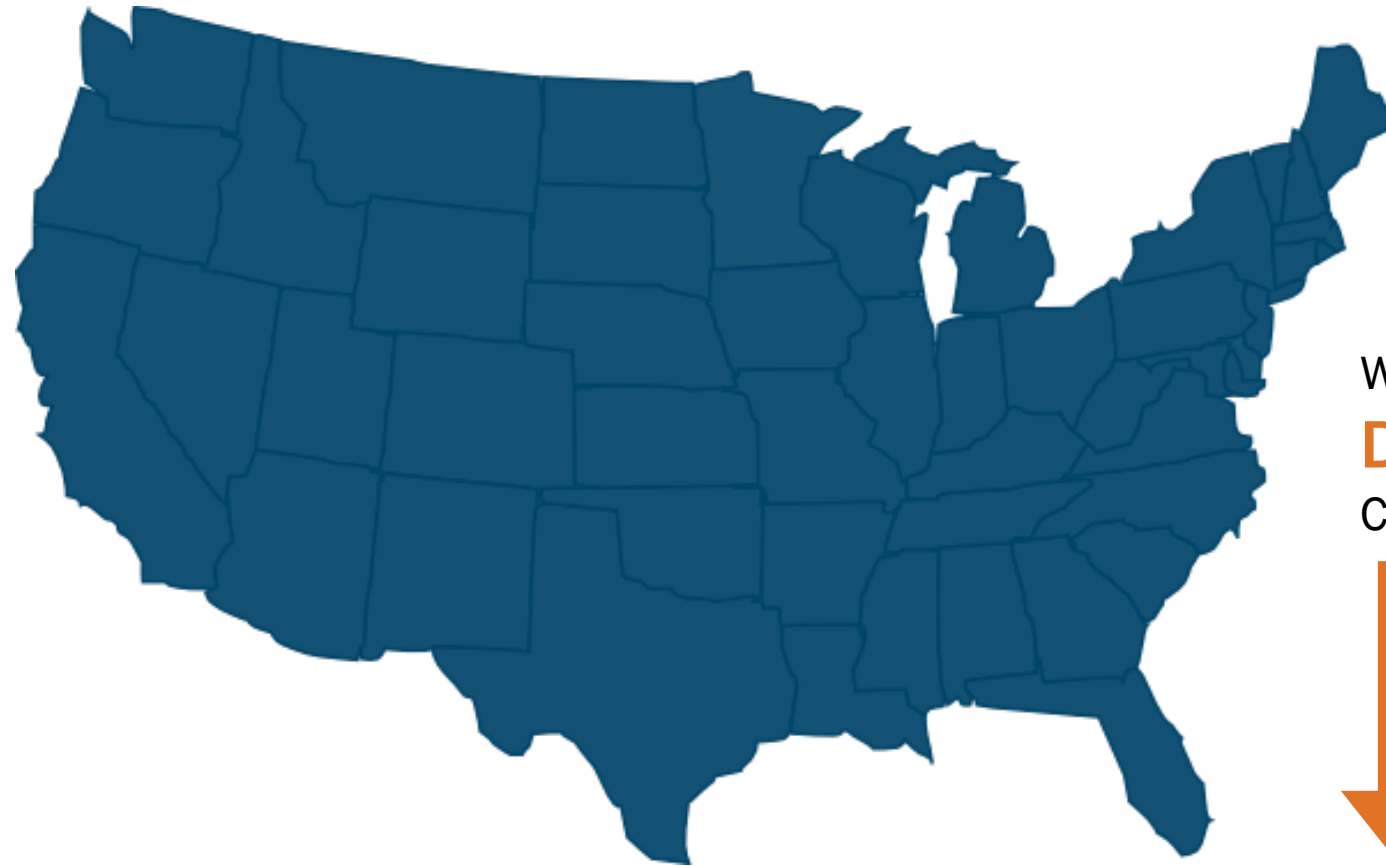
U.S. manufacturing subsector...



CONTRIBUTES
\$2.35 trillion to
the U.S. Economy

GENERATES
11% of U.S. GDP

CREATES
11.4 million jobs



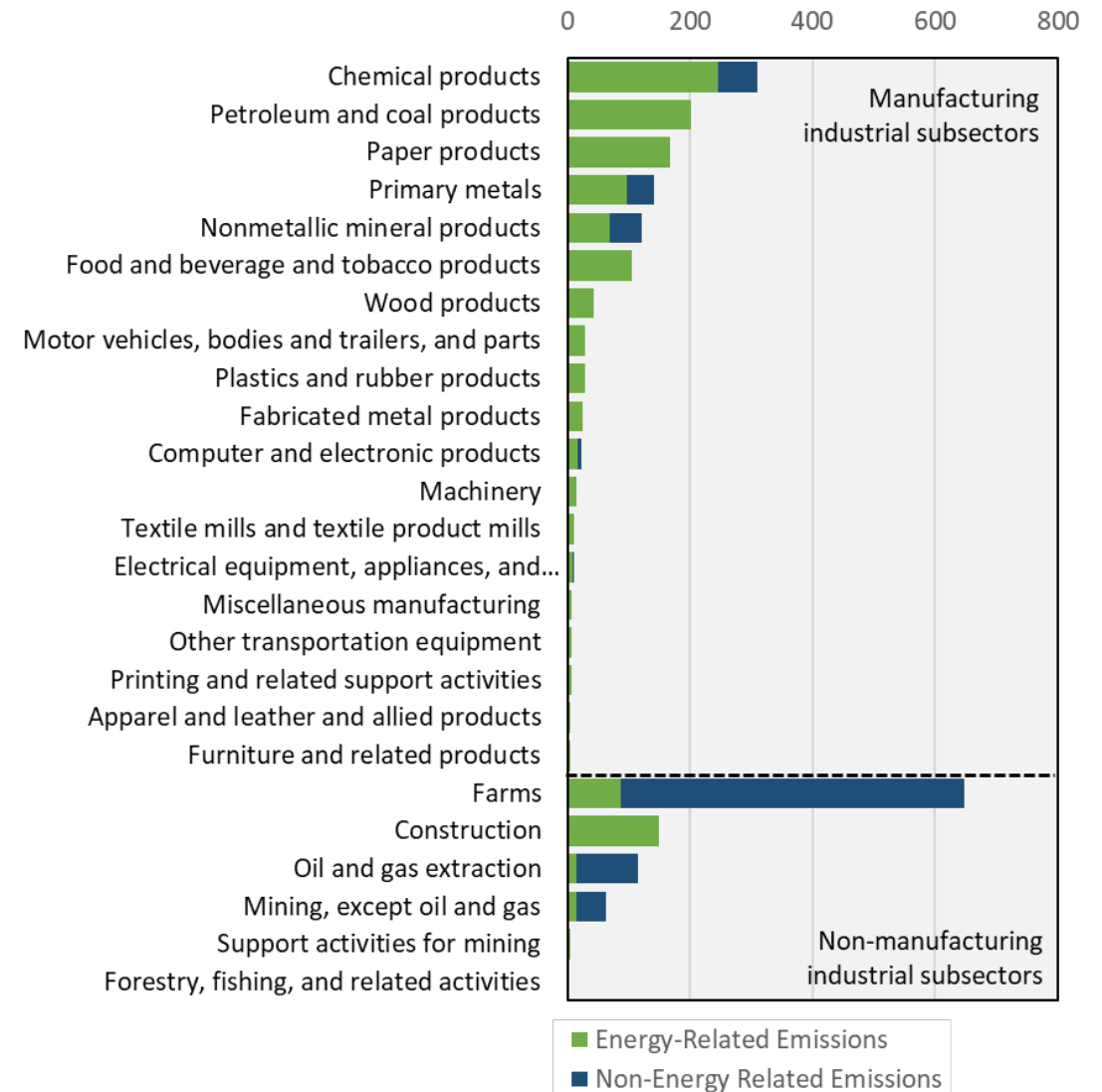
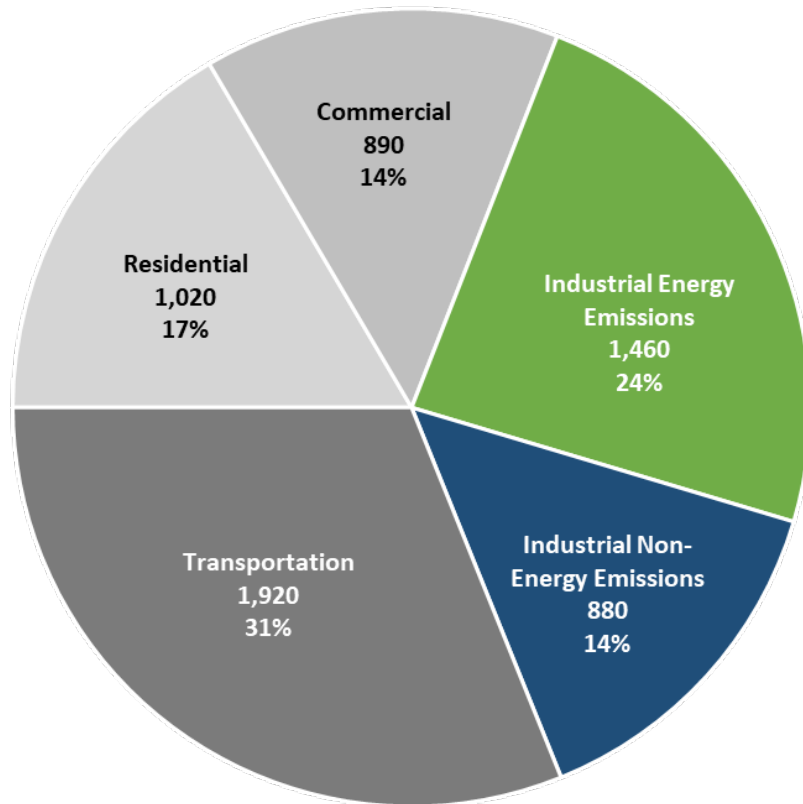
While working to
DECREASE
CO₂ emissions



38% of Total U.S.
Greenhouse Gas
Emissions

Industrial Decarbonization Challenge by Industry

U.S. Greenhouse Gas Emissions, 2018
(million metric tons CO₂eq)



Systemic barriers to industrial decarbonization

Investment scale → In the range of

\$700 Billion –

1.1 Trillion

just for 8 industrial sector of focus in the IRA :



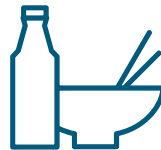
Chemicals



Refining



Iron &
Steel



Food &
Beverage



Cement



Pulp &
Paper



Aluminum



Glass

Estimated that

60% 

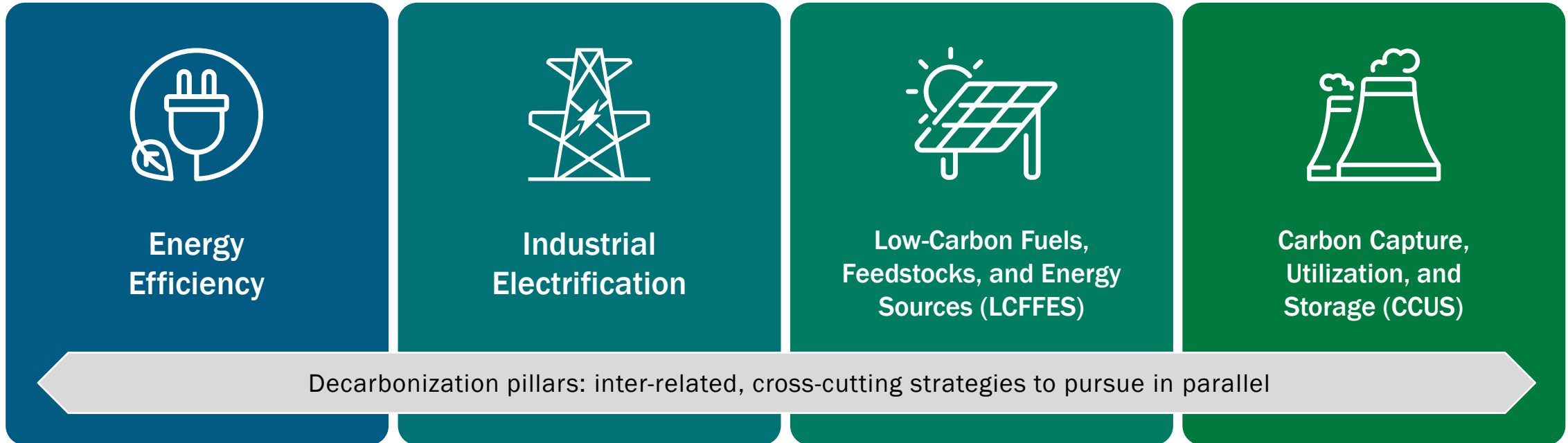
by 2030 will come from technologies that are not net-positive decarbonization levers with existing IRA tax credits or require further R&D to address

Targeted investment for research, development, and pilot-scale demonstrations is a need and opportunity for U.S. manufacturing

Source: DOE Pathways to Commercial Liftoff; Industrial Decarbonization https://liftoff.energy.gov/wp-content/uploads/2023/10/LIFTOFF_DOE_Industrial-Decarbonization_v8.pdf

DOE Industrial Decarbonization Roadmap

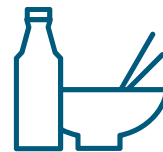
Industrial Decarbonization Pillars



Iron & Steel



Chemicals



Food & Beverage



Petroleum Refining



Cement



www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Industrial Efficiency and Decarbonization Office (IEDO)

Leads the development and accelerates the adoption of sustainable technologies that increase efficiency and eliminate industrial GHG emissions.

Energy- and Emissions-Intensive Industries



- Iron & Steel
- Chemicals
- Food & Beverage
- Forest Products
- Cement & Concrete

Cross-Sector Technologies



- Thermal Processes & Systems
- Low-Carbon Fuels, Feedstocks, & Energy Sources
- Emerging Efficiency
- Water & Wastewater Treatment

Technical Assistance & Workforce Development



- Better Plants Program
- Onsite Energy Technical Assistance Partnerships (TAPs)
- 50001 Energy Management Programs

IEDO Funding Announcements

FY22 Industrial Efficiency and Decarbonization:

- \$135M for 40 projects to decarbonize the five highest-emitting industrial subsectors

FY23 IEDO Multi-Topic:

- \$171M for 49 projects to advance high-impact applied RD&D projects to decarbonize the U.S. industrial sector. Includes sector-specific and cross-sector approaches

Decarbonization of Water Resource Recovery Facilities:

- \$27.8M for 10 projects to decarbonize the entire life cycle of Water Resource Recovery Facilities

Electrified Processes for Industry without Carbon (EPIXC) Institute

- \$70M over 5 years to bridge the gap between research and commercialization for novel electrification processes; and mobilize an innovation ecosystem of private companies, National Labs, universities, labor unions and community partners

Rapid Advancement in Process Intensification Deployment (RAPID) Institute:

- \$40M for a second 5-year phase to drive more resilient, lower cost, and reduced energy and carbon footprint manufacturing in the chemical process industries

National Alliance for Water Innovation (NAWI) Hub

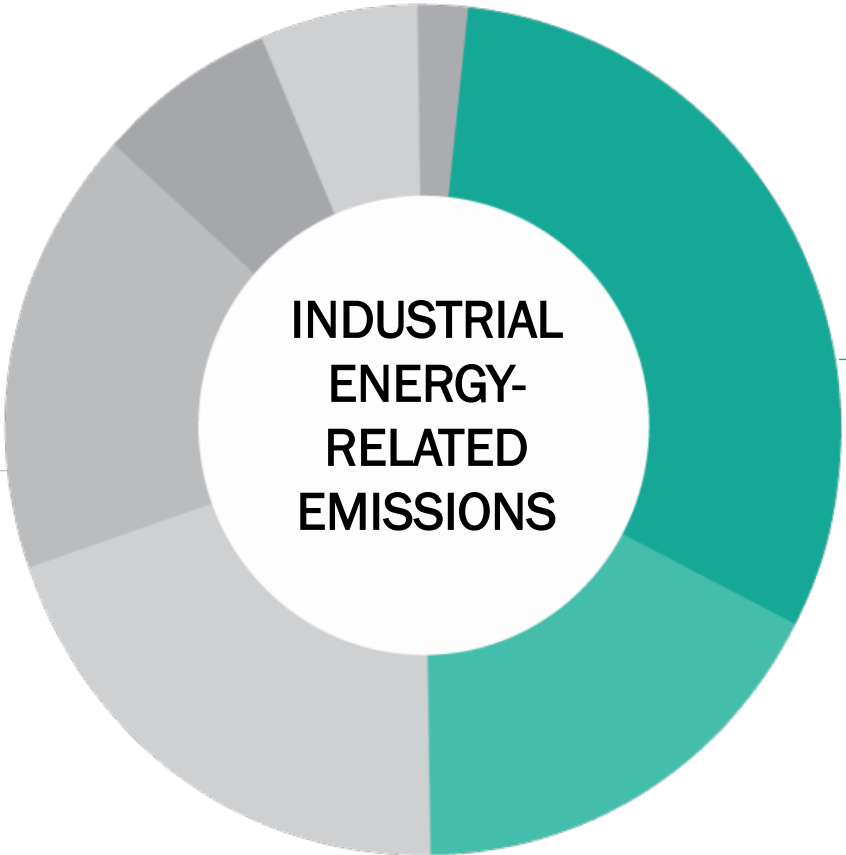
- \$75M for a 5-year renewal of DOE's Energy-Water Hub focused on desalination and water-treatment technologies to secure affordable and energy efficient water supplies from nontraditional water sources

\$ Half billion
over 2 years

Expanded Approach for All of Industry

The 6 heavy emitting subsectors currently being evaluated:

- Iron/steel
- Pulp/paper
- Chemicals
- Food/beverage
- Refining
- Cement/concrete



THE REST OF INDUSTRY

- Other Manufacturing
- Construction
- Mining, Oil, & Gas
- Water & Wastewater Treatment
- Agriculture & Forestry
- Data Centers

The rest of industry represents nearly half of the industrial sector's energy-related emissions.

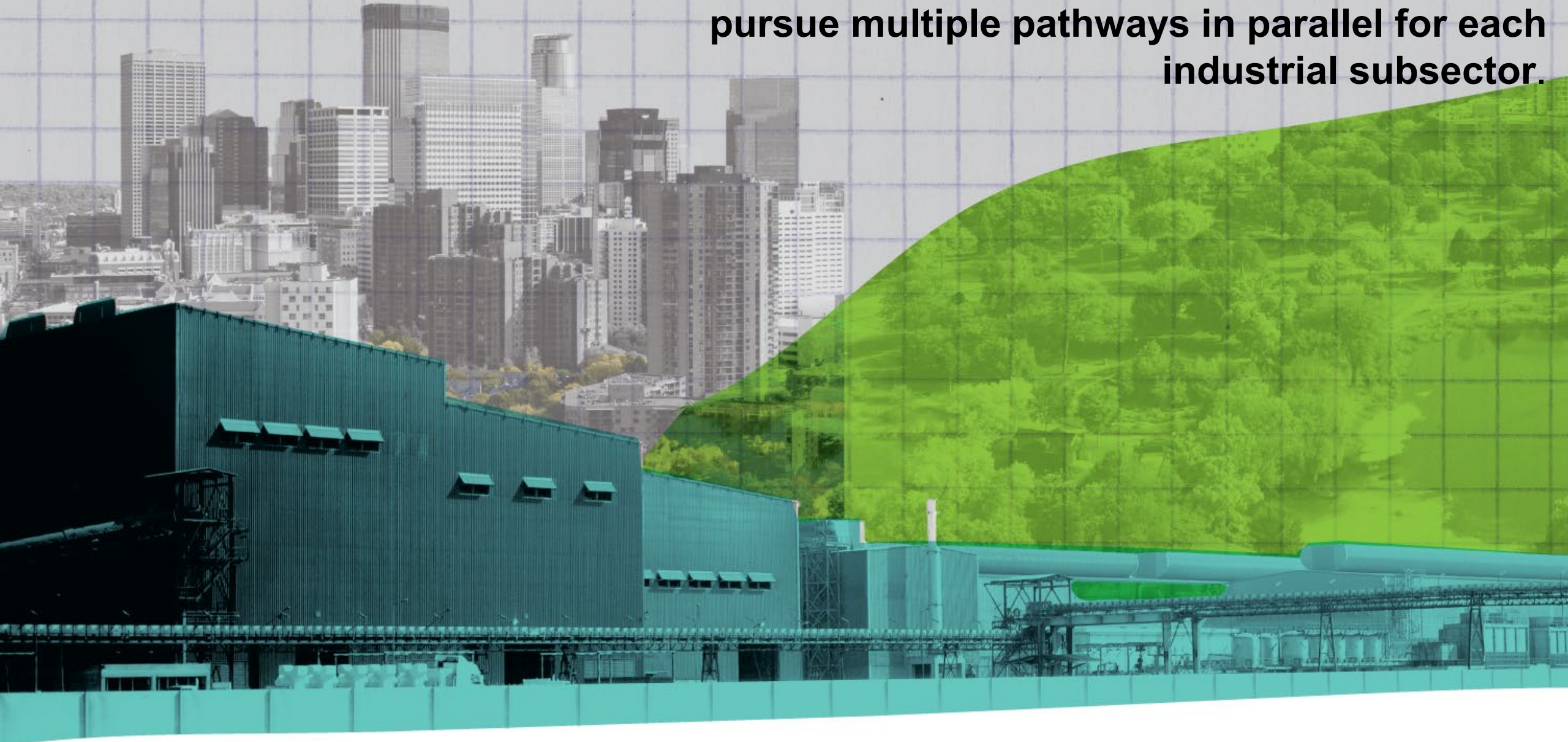
The Path Forward

Building on the foundation of Roadmap, DOE is conducting a new holistic vision study. *Pathways for U.S. Industrial Transformations: Unlocking American Innovation* will:

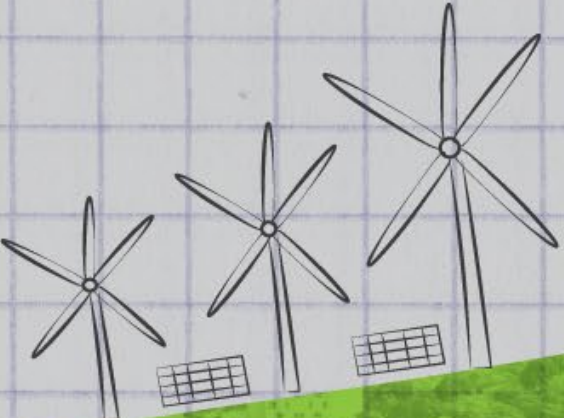
- Identify **cost-effective and industry-specific strategic pathways** to achieve a thriving U.S. industrial sector with net-zero greenhouse gas (GHG) emissions by 2050
- Address the **technological, economic, societal, and environmental & health impacts** associated with the scale and pace of an industrial transformation.
- Present **strategies, targeted pathways, metrics, and targets**, for overcoming challenges and barriers.

Reimagining the Industrial Sector of the future

There is no single pathway to decarbonization that will work for any single industrial subsector. **We must pursue multiple pathways in parallel for each industrial subsector.**



Decrease emissions



Onsite Energy

Thermal Storage

Process Efficiency
+ Carbon Capture

circularity



Transforming Industry: Strategies for Decarbonization RFI

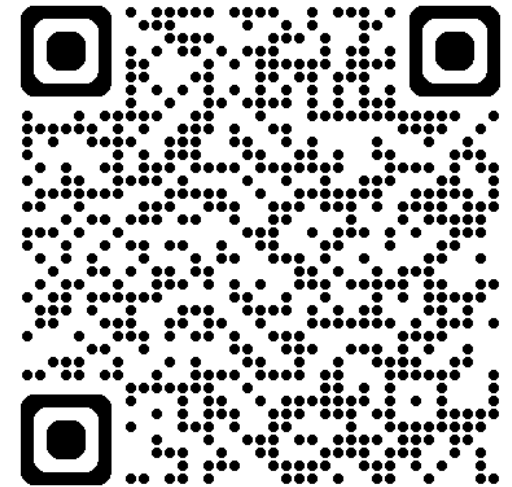
The RFI will inform the *Pathways for U.S. Industrial Transformations: Unlocking American Innovation* study:

IEDO seeks input on the following categories:

- Industrial Decarbonization Barriers, Challenges, and Cross-Cutting Strategies
- Framework for Industrial Decarbonization Pathways
- Impacts and Evaluation Criteria for Industrial Decarbonization Pathways; and
- Net-zero Decarbonization Pathways for Specific Industrial Subsectors

www.energy.gov/eere/iedo/industrial-decarbonization-pathways-modeling

Deadline for responses: June 10, 2024, at 5:00pm ET



Primary Challenges and Barriers to Industrial Decarbonization



Thermal Systems Emissions. Represent about half of all energy-related industrial emissions with over 90% due to fossil fuel combustion.



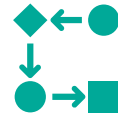
Process Emissions. Emissions from chemical or physical transformations are intrinsic to many current industrial processes – i.e., cement production.



Constraints within Industrial Entities. Industrial entities' operation and structure can limit zero-emissions technologies adoption and material and energy efficiency improvements in existing processes.



Decarbonization Infrastructure. All decarbonization pathways will require the expansion of decarbonization infrastructure.



Inefficient Information Flows. Data privacy concerns and lack of information sharing can impact the scale and speed of industrial decarbonization efforts.



Underrepresented Social Criteria. Protecting the workforce and associated communities that interact with industry is a priority during the clean energy transition.

Framework for Industrial Decarbonization Pathways



Net-Zero Emissions Pathway: A set of specific actions needed to achieve progress in and across the decarbonization pillars, while remaining informed and supplemented by RD&D to advance viable solutions that will need to be adopted at scale in the marketplace.

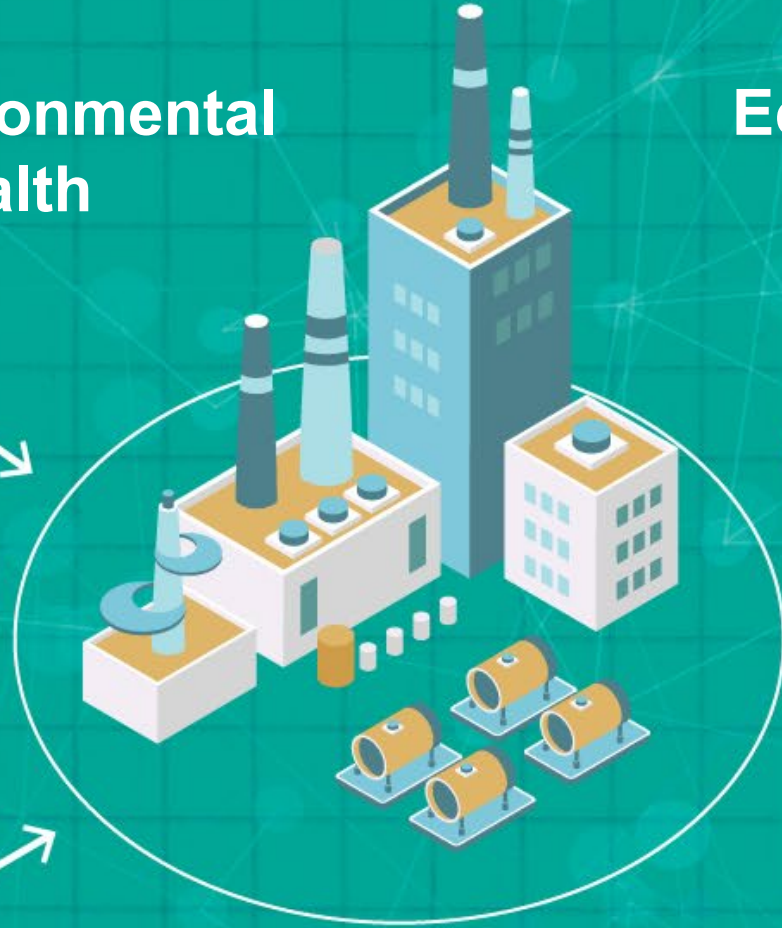
- Major production routes
- Emissions reduction
- Factors impacting how facilities will evaluate and choose technologies
- Timing for technology deployments
- Major uncertainties, risks, and barriers
- Prioritization of retrofits and greenfield facilities



**Environmental
& Health**



Economic



Societal



Technological



Beyond the Plant Bounds: Impacts and Evaluation Criteria



- Direct and indirect CO₂ emissions.
- Criteria air pollutants, toxics, other air and water pollutants, waste, thermal pollution, and land use.
- Associated health impacts.



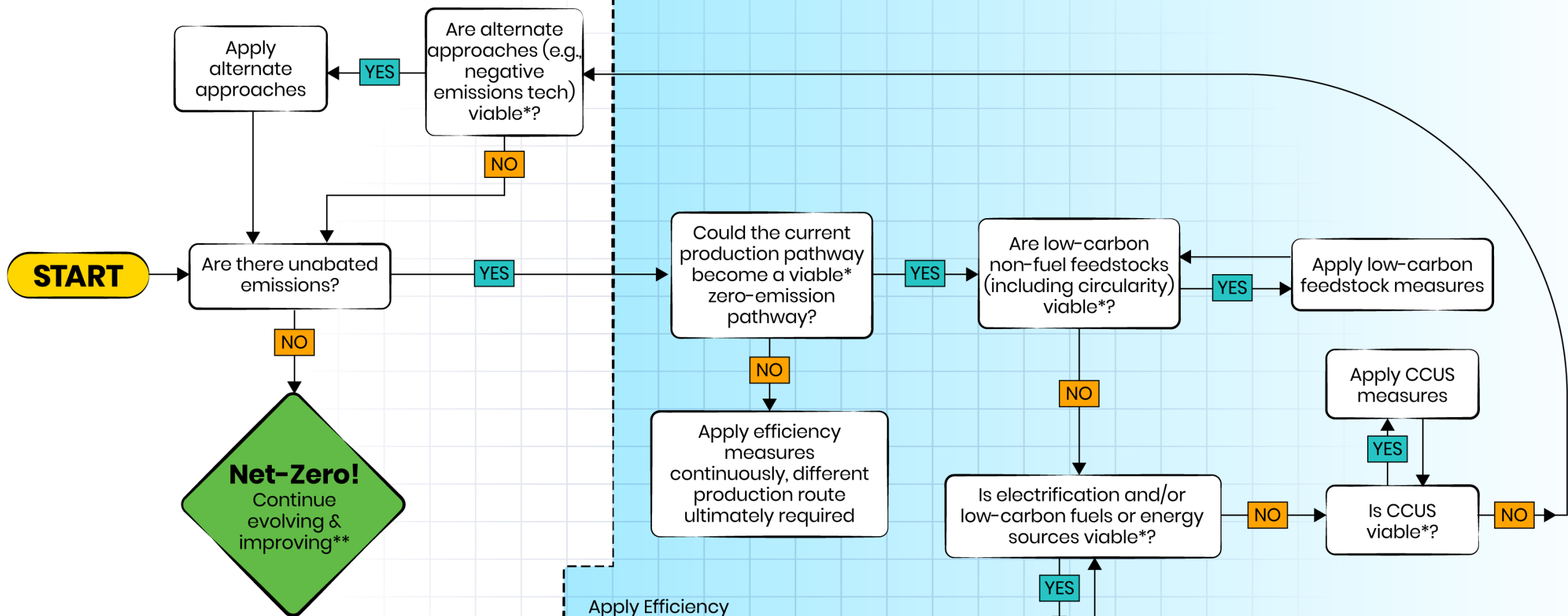
- Equity and environmental justice.
- Energy costs and infrastructure impacting Americans
- Workforce with high-quality jobs.
- National security, critical materials, and resilient supply chains.



- Cost of abating carbon or producing a carbon-abated product.
- Cost of heat (or clean energy) or cost of material transformation.
- Deployment costs.
- Demand incentives, future regulatory or market drivers, competitiveness, and resilience.



- Energy intensity of finished products.
- Performance parameters.
- Operational factors.
- Scalability, technology or resource availability, and critical material use.
- Required expertise of workforce.



INDUSTRIAL
DECARBONIZATION
Decision Tree

Apply Efficiency
(energy efficiency,
energy storage, and
materials efficiency)
Measures & Principles

*Viable implies currently available, cost-effective, and that the measures are deemed effective through social and environmental criteria and necessary

** Morrow, William III et al. 2017. "U.S. Industrial Sector Energy Productivity Improvement Pathways." [U.S. Industrial Sector Energy Productivity Improvement Pathways \(aceee.org\)](https://www.aceee.org)

Transforming Industry: Strategies for Decarbonization RFI

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