U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

Developing a Roadmap and Strategy for Industrial Decarbonization

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Industrial Efficiency and Decarbonization Office

IEDO Food & Beverage Workshop
August 31, 2023 | Las Vegas, NV

Argonne NATIONAL LABORATORY

NREL Transforming ENERGY

OAK RIDGE National Laboratory

BERKELEY LAB Lawrence Berkeley National Laboratory

energetics Clean Energy Consulting

Agenda

- DOE Industrial decarbonization roadmap, modeling & related efforts
- IEDO Strategic Planning
- Building on the Roadmap and Looking Forward

U.S. Industry's Significant Energy Demand and CO_2 Emissions

Industrial sector is comprised of
manufacturing | agriculture | mining | construction

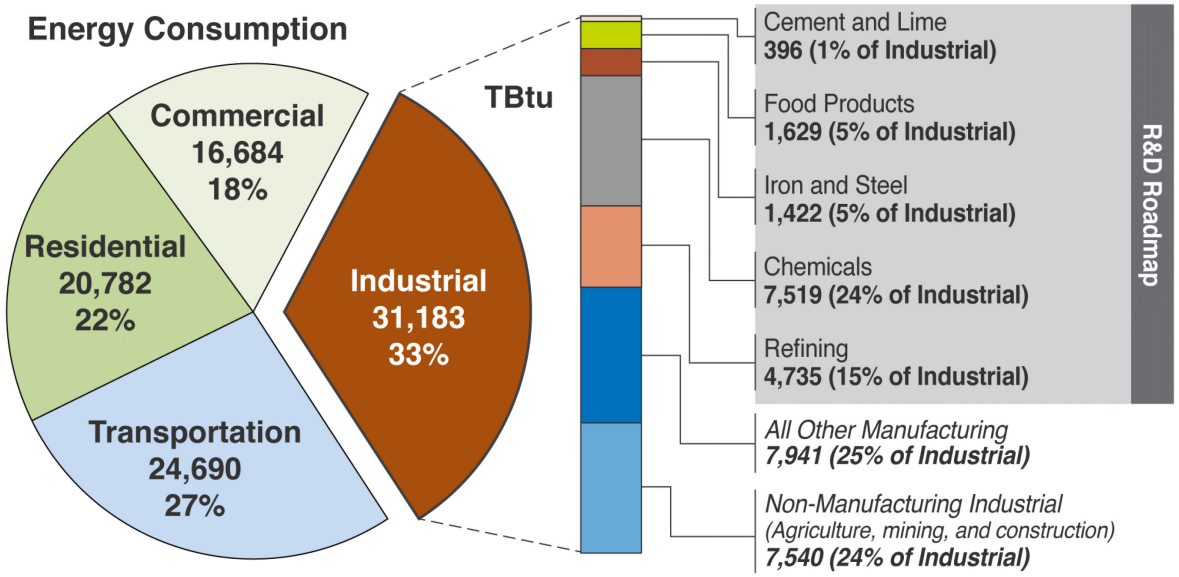
ACCOUNTS FOR

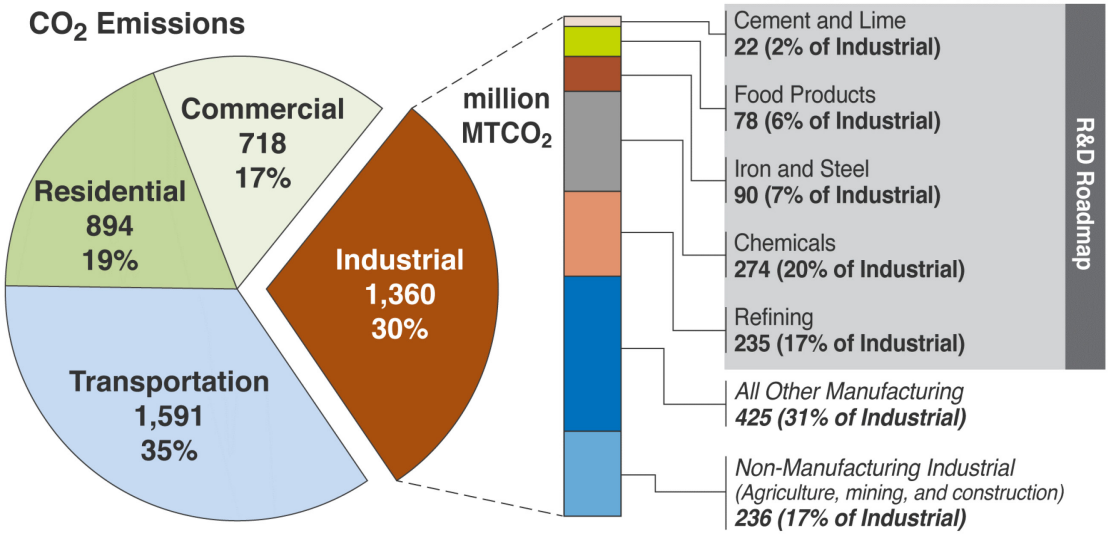
33% of the nation's primary energy use

30% of related CO_2 emissions

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

17% CO_2 emissions increase





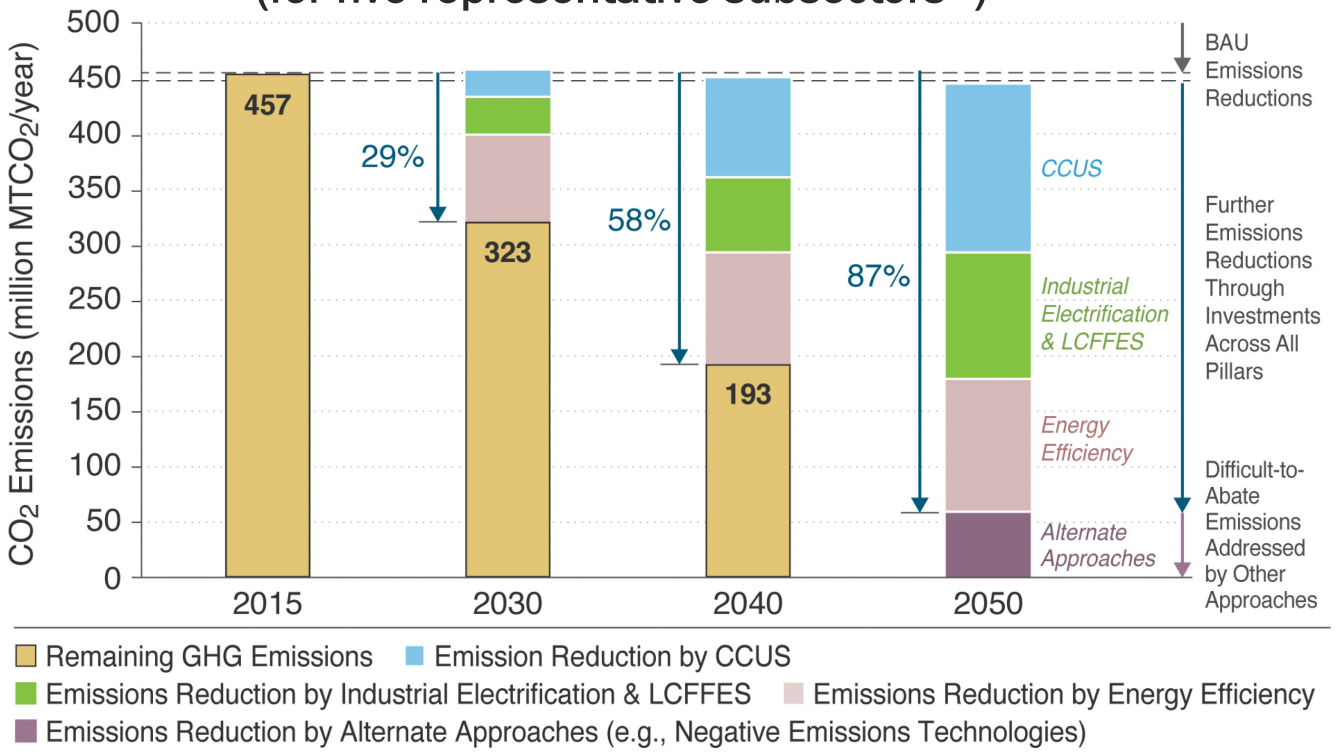
EIA, *Annual Energy Outlook 2020 with Projections to 2050*. Source: Industrial Decarbonization Roadmap.

Source: DOE Industrial Decarbonization Roadmap, Sept. 2022. https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

2050 Industrial Emissions Reductions Potential

Near-Zero GHG Emissions Scenario

(for five representative subsectors*)



Roadmap Recommendations

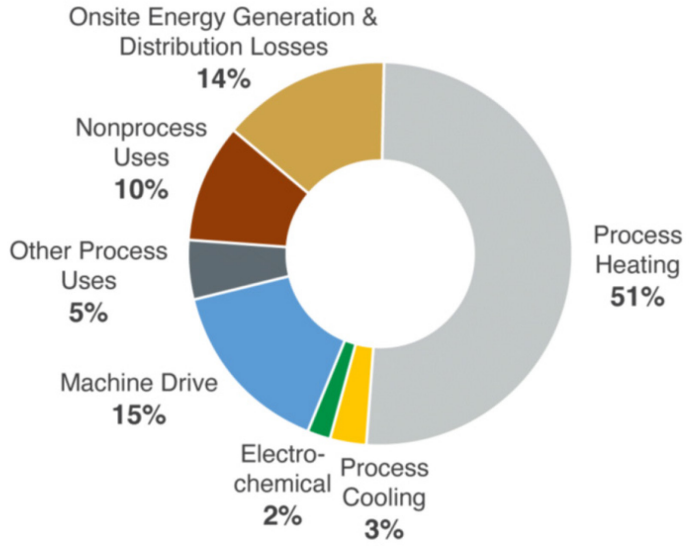
- Advance Early-Stage RD&D
- Invest in Multiple Process Strategies
- Scale through Demonstrations
- Address Process Heating
- Decarbonize Electricity Sources
- Integrate Solutions
- Conduct Modeling and System Analyses
- Engage Communities, Develop a Thriving Workforce

***Subsectors included in Roadmap analysis:** Iron & Steel, Chemicals, Food & Beverage, Petroleum Refining, and Cement. *(Near zero GHG scenario, excluding feedstocks.*

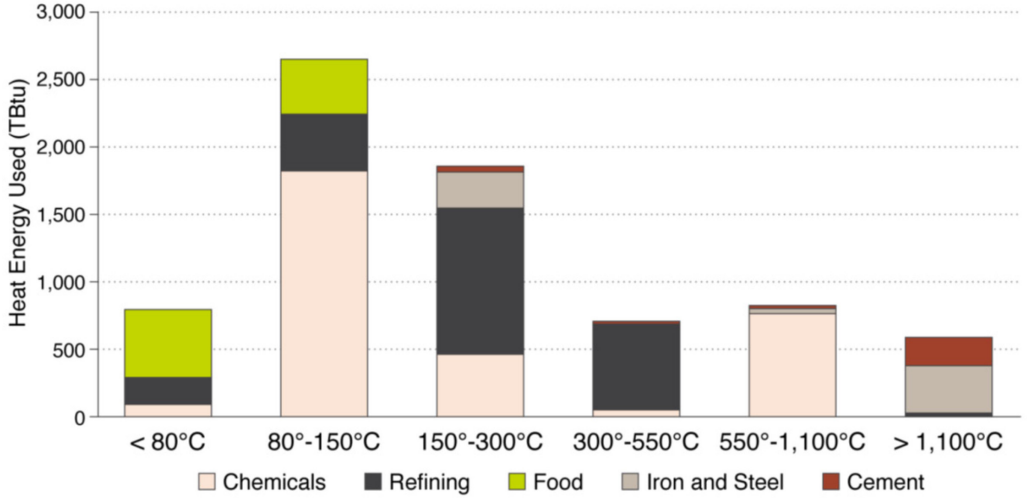
Source: DOE Industrial Decarbonization Roadmap, Sept. 2022. https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

No One-Size-Fits-All Solution

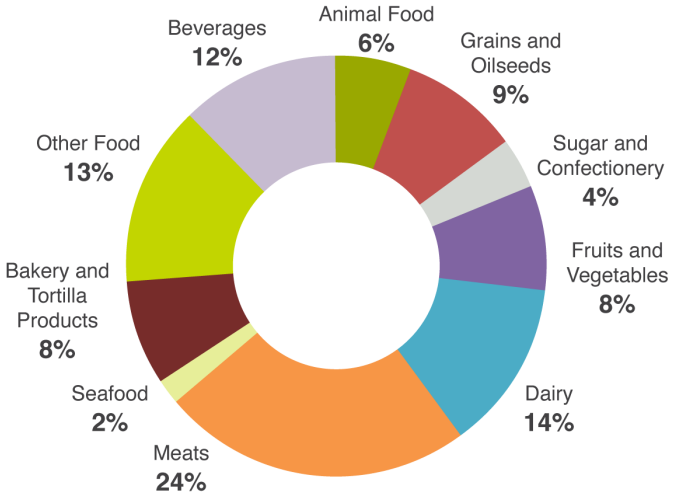
Manufacturing Sector Onsite Energy Use



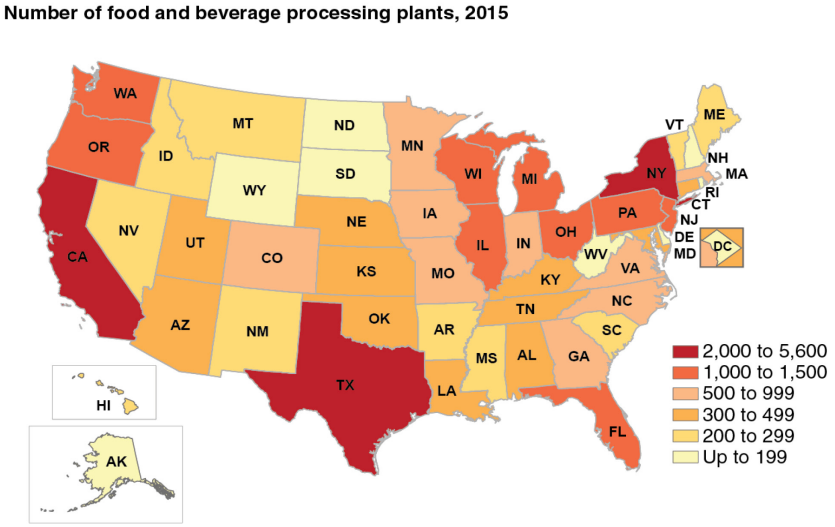
Distribution of Process Heat in Mfg.



F&B products are diverse



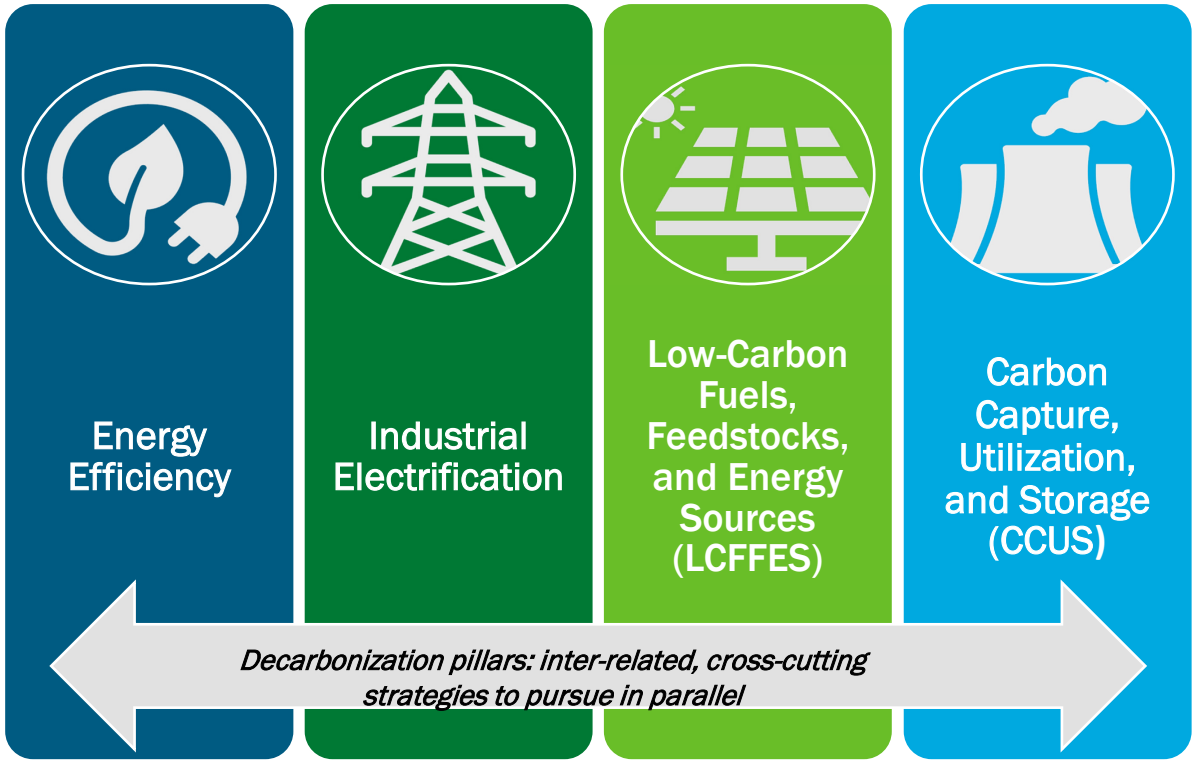
F&B facilities are numerous and distributed across the U.S.



Source: USDA, Economic Research Service using data from the U.S. Census Bureau's County Business Patterns.

DOE Industrial Decarbonization Roadmap - Pillars and Sector Focus Areas

Industrial Decarbonization Pillars



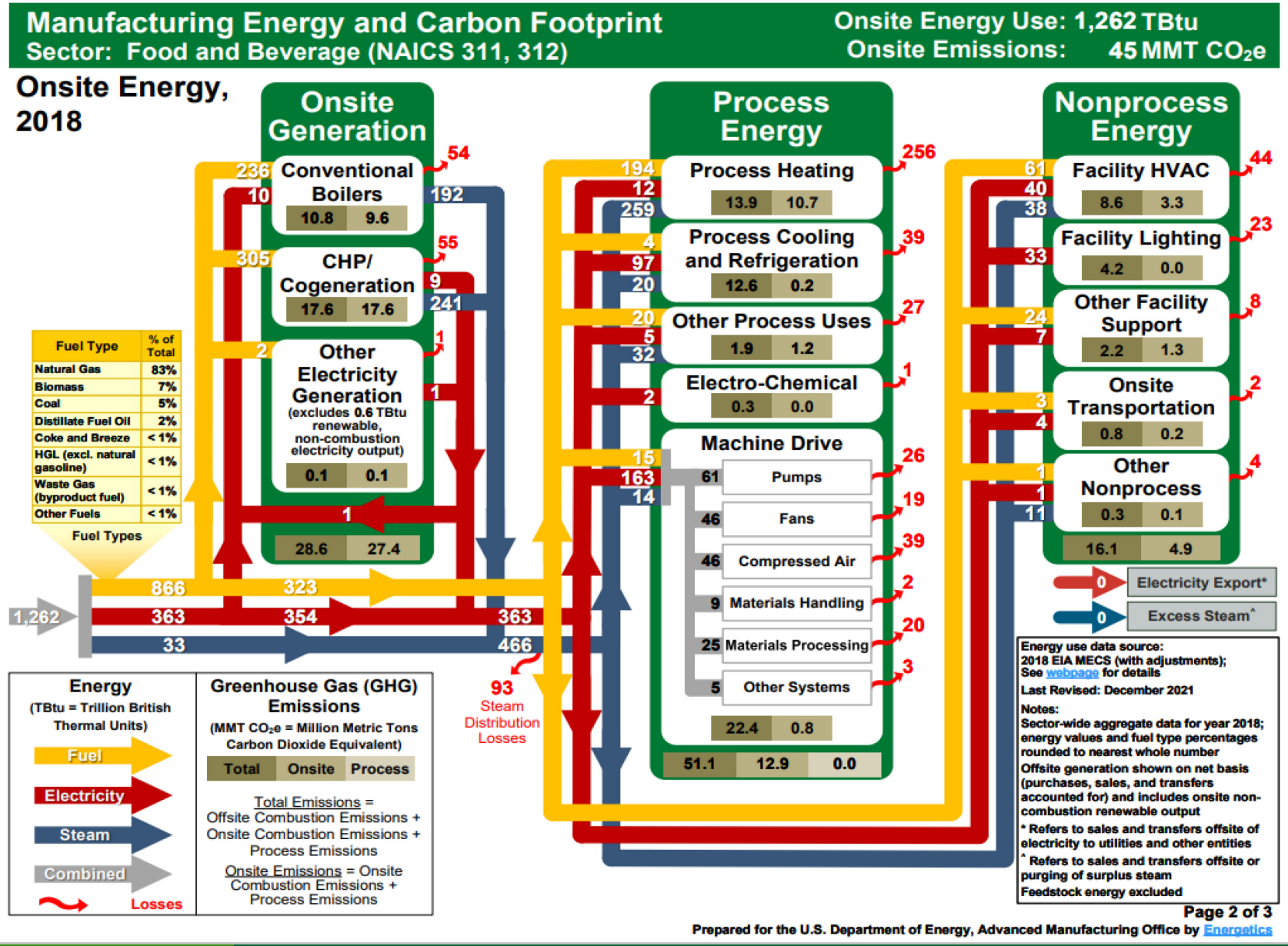
Food & Beverage

1,629 TBtu

78 MMT energy-related CO_2e

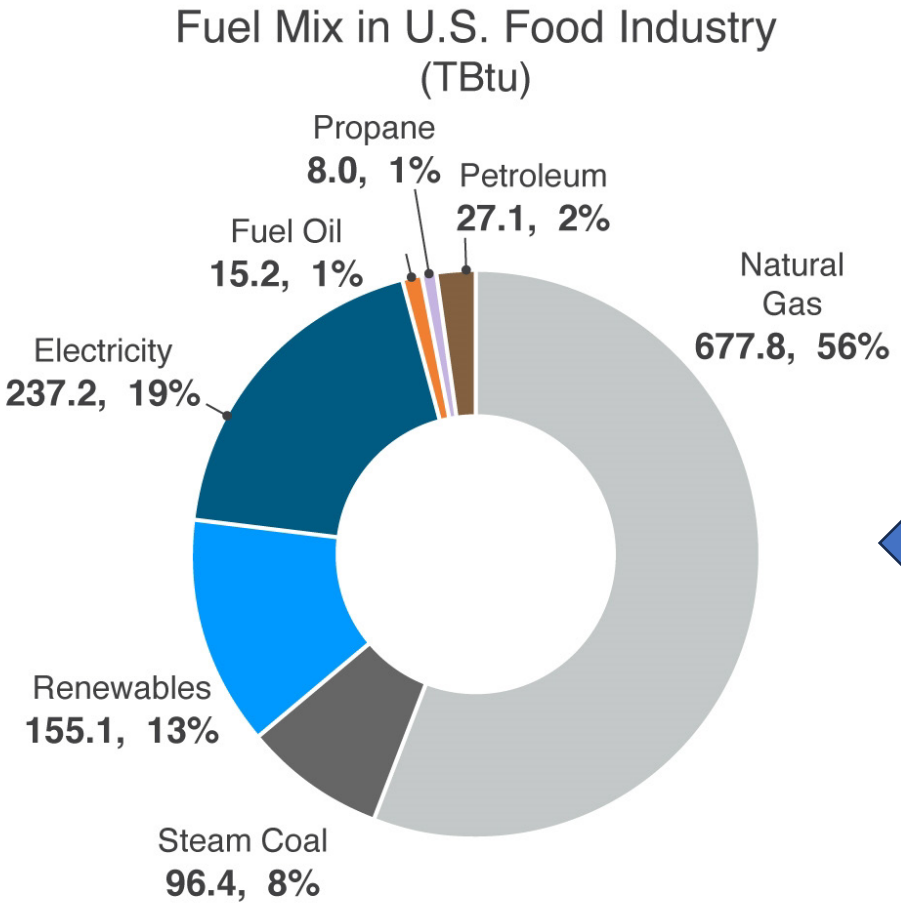
Annual Energy Outlook 2021 with Projections to 2050," U.S. Energy Information Administration, February 3, 2021, https://www.eia.gov/outlooks/archive/aeo21/. See Table 19. Energy-Related Carbon Dioxide Emissions by End Use.

Energy & Carbon Footprints

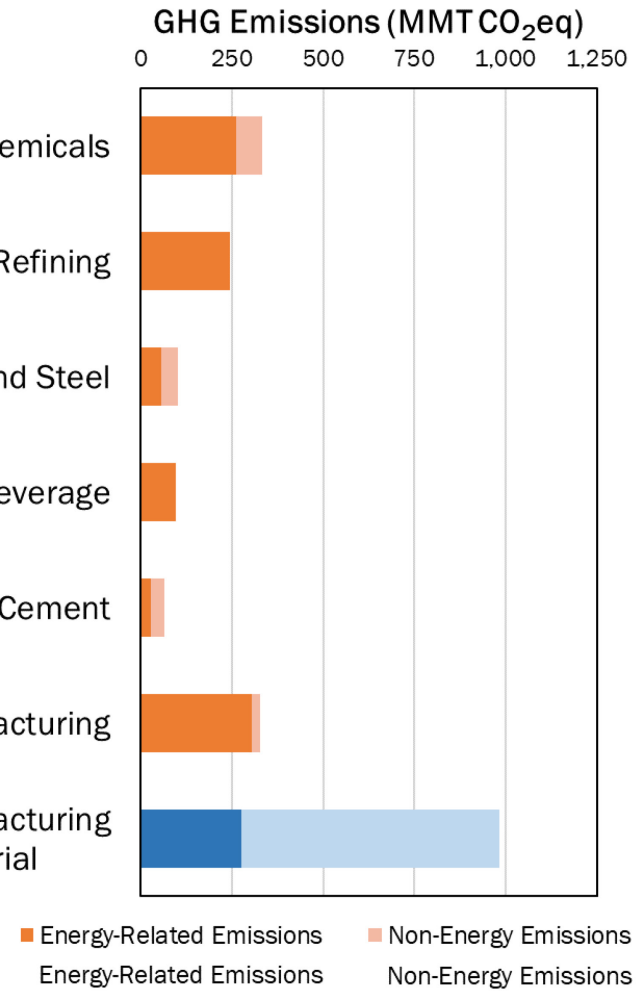


https://www.energy.gov/eere/iedo/manufacturing-energy-and-carbon-footprints-2018-mecs

Energy Demand and CO_2 Emissions



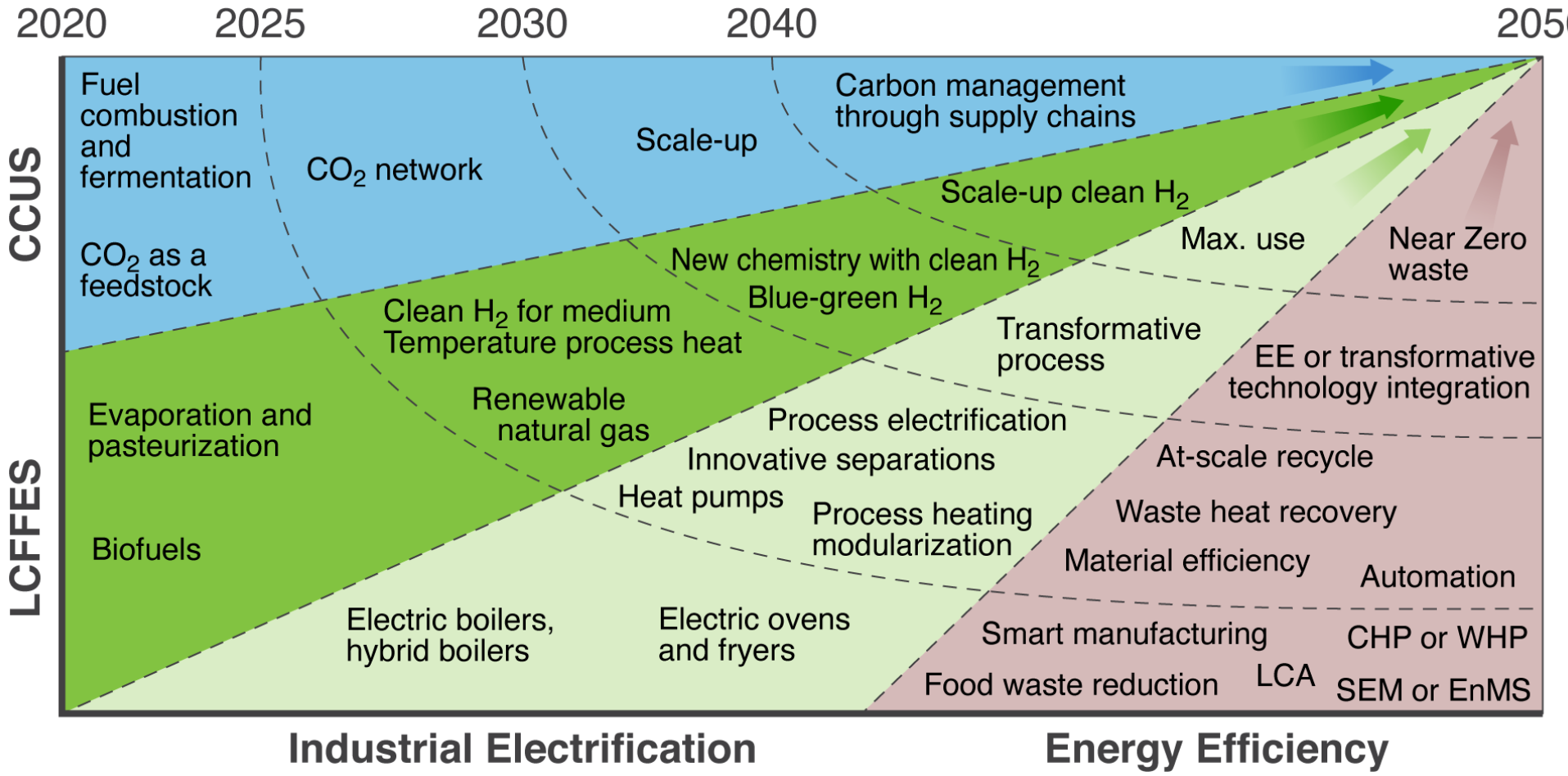
Total Industry Emissions, 2018
(energy-related + non-energy; million metric tons CO_2eq)



EIA, *Annual Energy Outlook 2020 with Projections to 2050*. Source: Industrial Decarbonization Roadmap.

EIA Monthly Energy Review, Manufacturing Energy Consumption Survey; EPA GHGRP Inventory

Industrial Decarbonization is also a systems challenge



Landscape of major RD&D investment opportunities for industrial decarbonization between now and 2050.

LCFFES = Low Cost Fuels, Feedstocks, and Energy Sources; **CCUS** = Carbon Capture Utilization and Storage

GHG reductions require approaches at multiple levels:

- Core process
- Facility
- Beyond plant bounds

What are the implications of:

- Expanded H_2 generation & use
- New thermal energy sources & systems
- Smart manufacturing, automation, & data analytics
- Transition to clean electricity
- Policies

Source: DOE Industrial Decarbonization Roadmap, Sept. 2022. https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Representative Food & Beverage Opportunities

- Shift to electric ovens, fryers, boilers, and other electrified technologies where possible, as grid decarbonizes.

- Reduce food waste throughout the supply chain through methods identified in LCAs and collaboration between manufacturers.

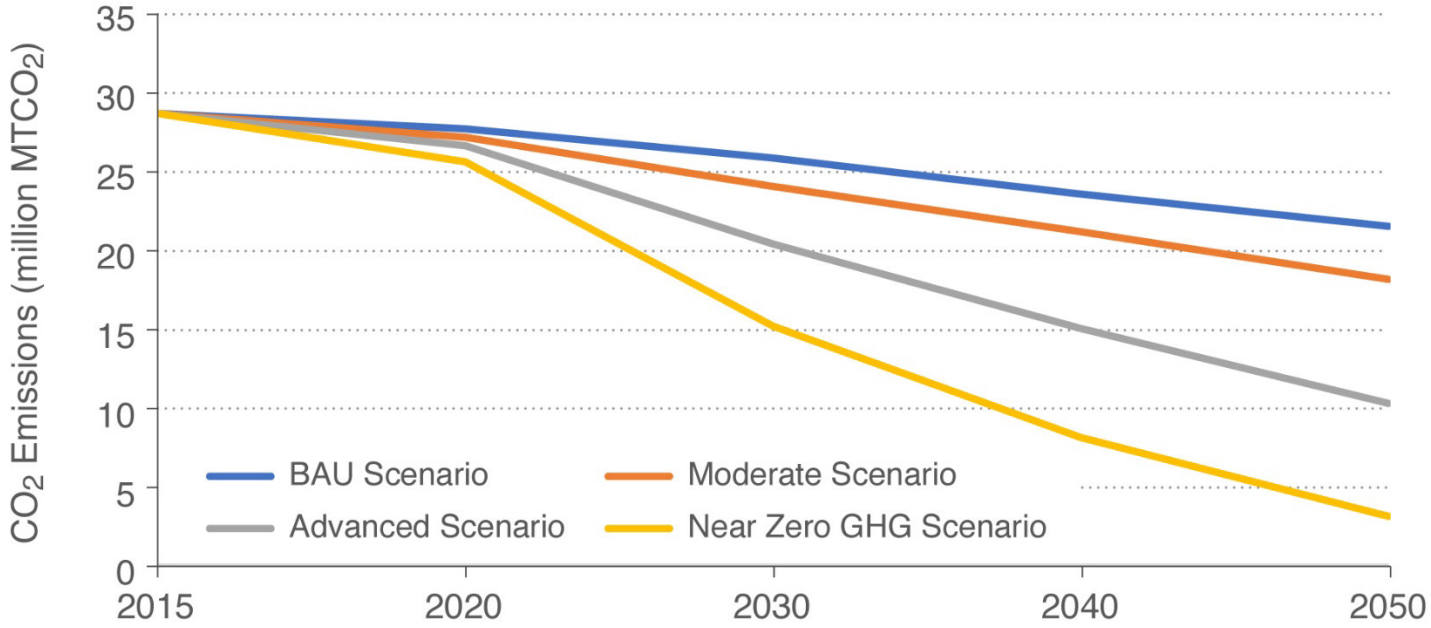
- Increase RD&D into heat pumps to recover and supply process heat in food and beverage manufacturing processes.

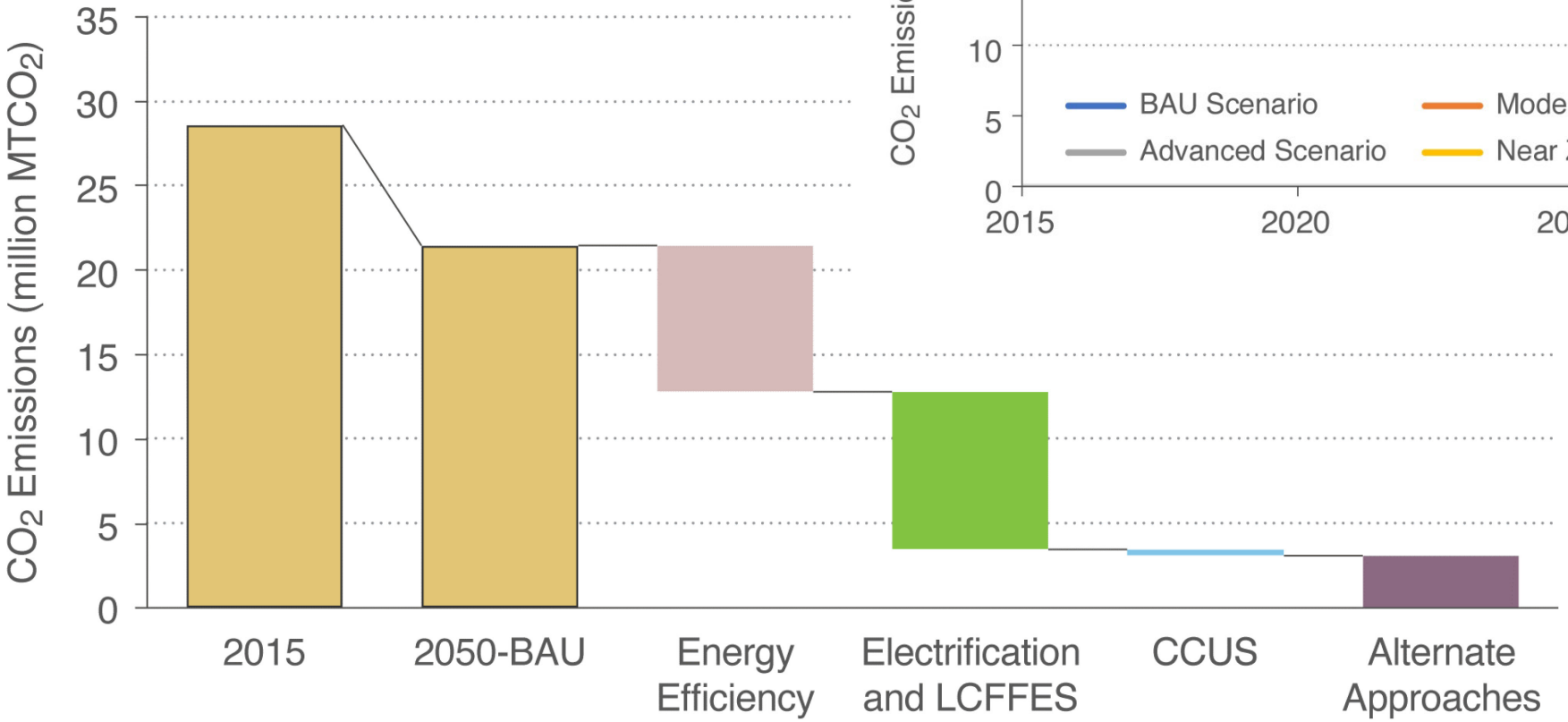
- Pursue recycling and material efficiency through methods like alternative packaging and packaging waste reduction.

- Invest in RD&D into transformative technologies.

Source: DOE Industrial Decarbonization Roadmap, Sept. 2022. https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Food & Beverage - Pathways to GHG Emissions Reductions





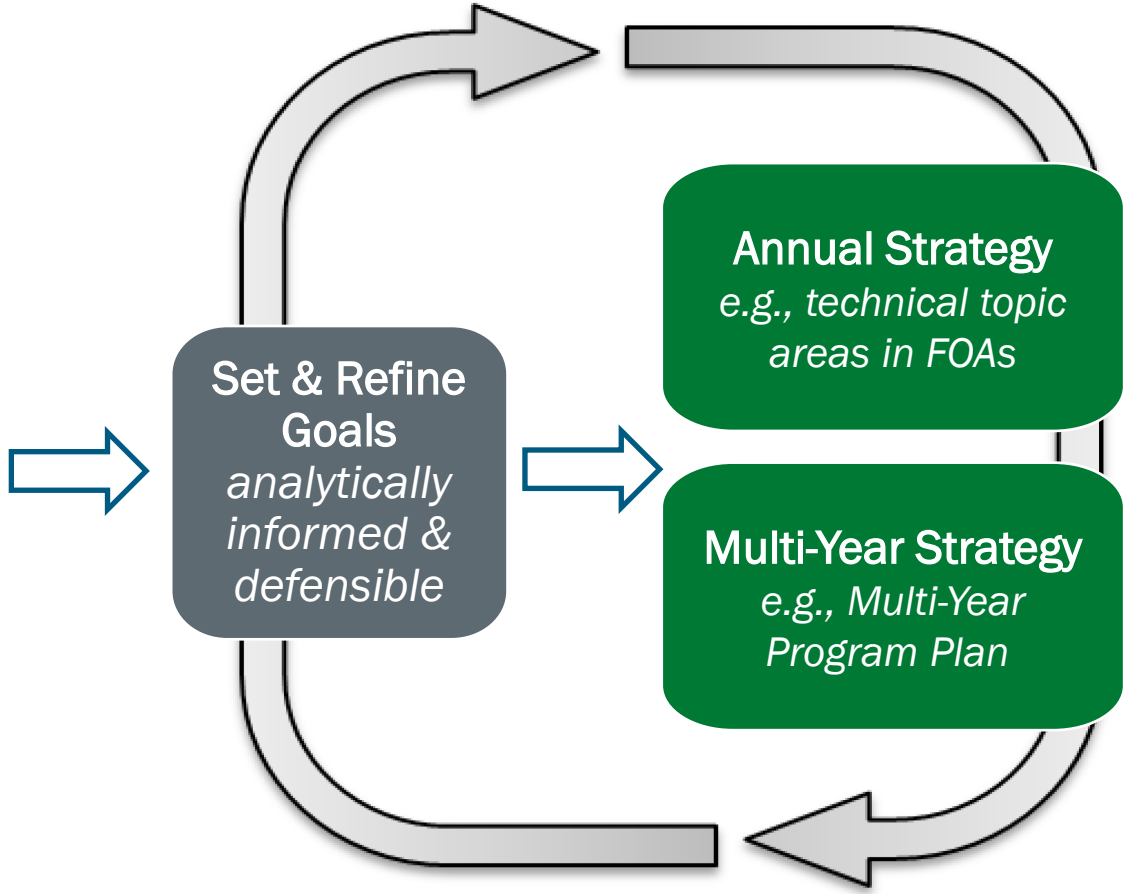
Source: DOE Industrial Decarbonization Roadmap, Sept. 2022. https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Roadmap is a only a start for IEDO Strategy & Planning

Technology data & Information
e.g., energy & emissions data

Targeted Analysis
e.g., LCA/TEA for a specific technology*

Integrating Analysis
e.g., systems modeling



GOAL:

National & global impact

** Life cycle analysis/Technoeconomic analysis*

Going Forward – Deeper Mapping of Opportunities to Impacts

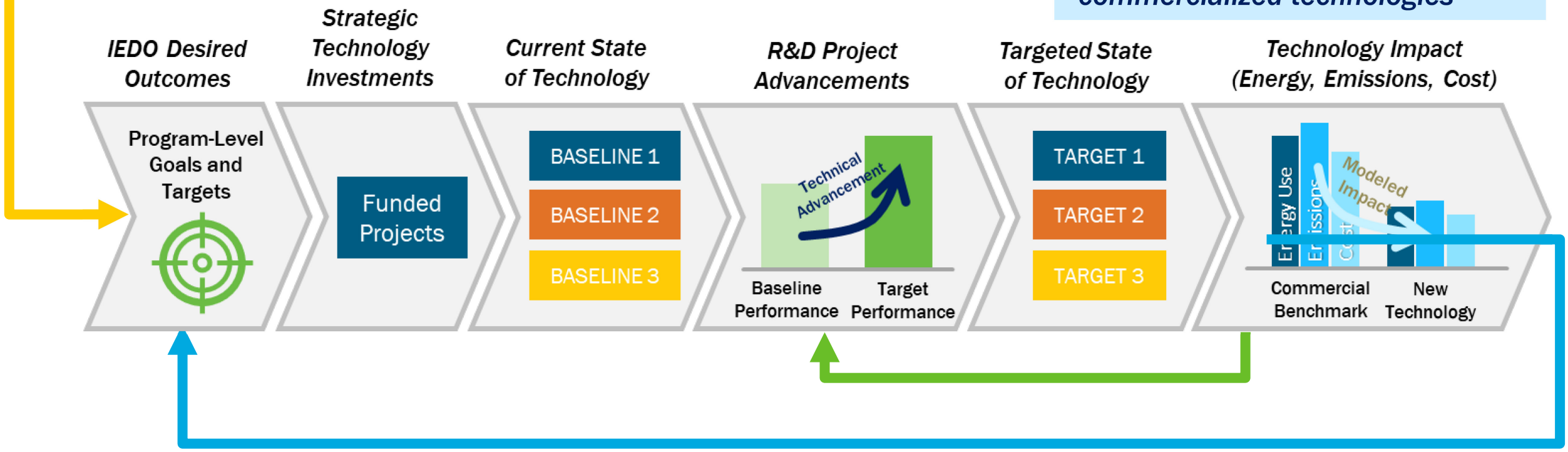
Low-Carbon Fuels and Electrified Heating	Energy Efficiency	Water Treatment and Management	Materials Efficiency
Low-carbon fuels or electrification for steam boilers	Low-carbon fuels or electrification for steam boilers	Low-carbon fuels or electrification for steam boilers	Low-carbon fuels or electrification for steam boilers
Low-temperature waste heat recovery from process exhausts	**Low-temperature waste heat recovery from process exhausts**	Low-temperature waste heat recovery from process exhausts	Low-temperature waste heat recovery from process exhausts
Alternative protein products	Alternative protein products	Alternative protein products	**Alternative protein products**
Smart/Flexible manufacturing processes	**Smart/Flexible manufacturing processes**	Smart/Flexible manufacturing processes	Smart/Flexible manufacturing processes
Drying and dewatering innovations	Drying and dewatering innovations	**Drying and dewatering innovations**	Drying and dewatering innovations
Waste management and reduction	Waste management and reduction	Waste management and reduction	**Waste management and reduction**
Innovative cooling, refrigeration and freezing solutions	**Innovative cooling, refrigeration and freezing solutions**	Innovative cooling, refrigeration and freezing solutions	Innovative cooling, refrigeration and freezing solutions
Wastewater Recovery and Reuse	Wastewater Recovery and Reuse	**Wastewater Recovery and Reuse**	Wastewater Recovery and Reuse

Strategic Analysis in Context with Technology Investments

Prospective analysis
Emerging technology opportunities

Introspective analysis
Assess & communicate impacts of active projects/portfolio

Retrospective analysis
Synthesize learnings from commercialized technologies



Highlights from Current Analysis Areas

Sustainable Manufacturing, Material Flows, and Supply Chains

- Supply chain, circular economy, and technology adoption analysis
- Complex systems modeling for materials & resource efficiency strategies
- Industry-specific data analysis
- Social and environmental justice in manufacturing

Water-Energy-Land Nexus for Industry

- Food & agricultural considerations & impacts
- Water use impacts of decarbonization technologies
- Water-related climate risks for manufacturing
- Water/wastewater treatment infrastructure

Industrial Decarbonization

- Industrial modeling & pathways analysis
- Deep dives & analysis of roadmap pillar technologies
- Demand side materials (commodities) efficiency strategies
- Process optimization & intensification technologies

EEIO-IDA Scenario Modeling Tool

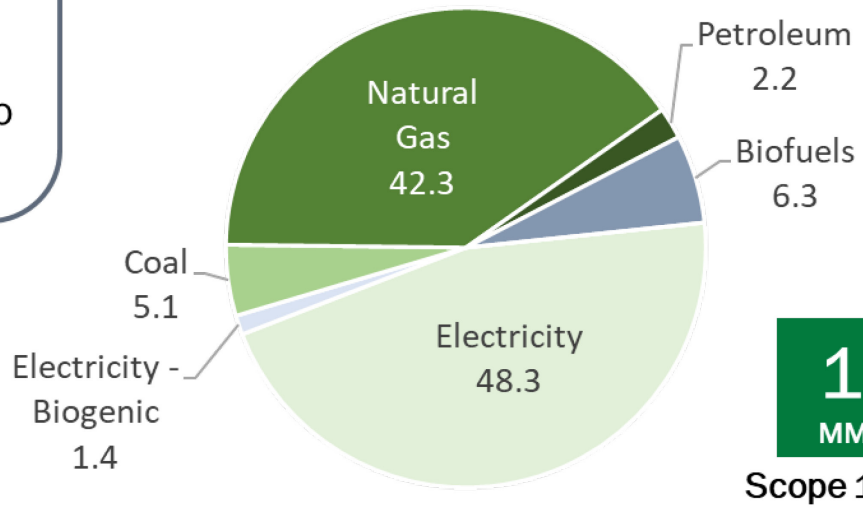
EEIO-IDA: Environmentally Extended Input-Output for Industrial Decarbonization Analysis

EEIO-IDA is a new Excel-based tool for rapid "what-if" analysis of sector-level industrial decarbonization opportunities, leveraging an environmentally extended input/output (EEIO) approach.

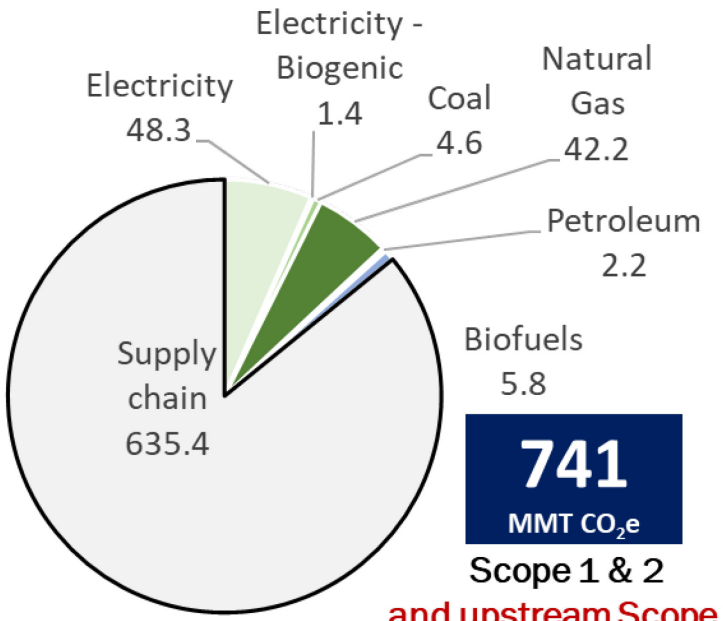
Tool automatically calculates scope 1, 2, and 3 emissions based on user assumptions and compares results to a 2018 base case

Food, beverage, and tobacco products

Direct GHG emissions
(million metric tons CO_2e)

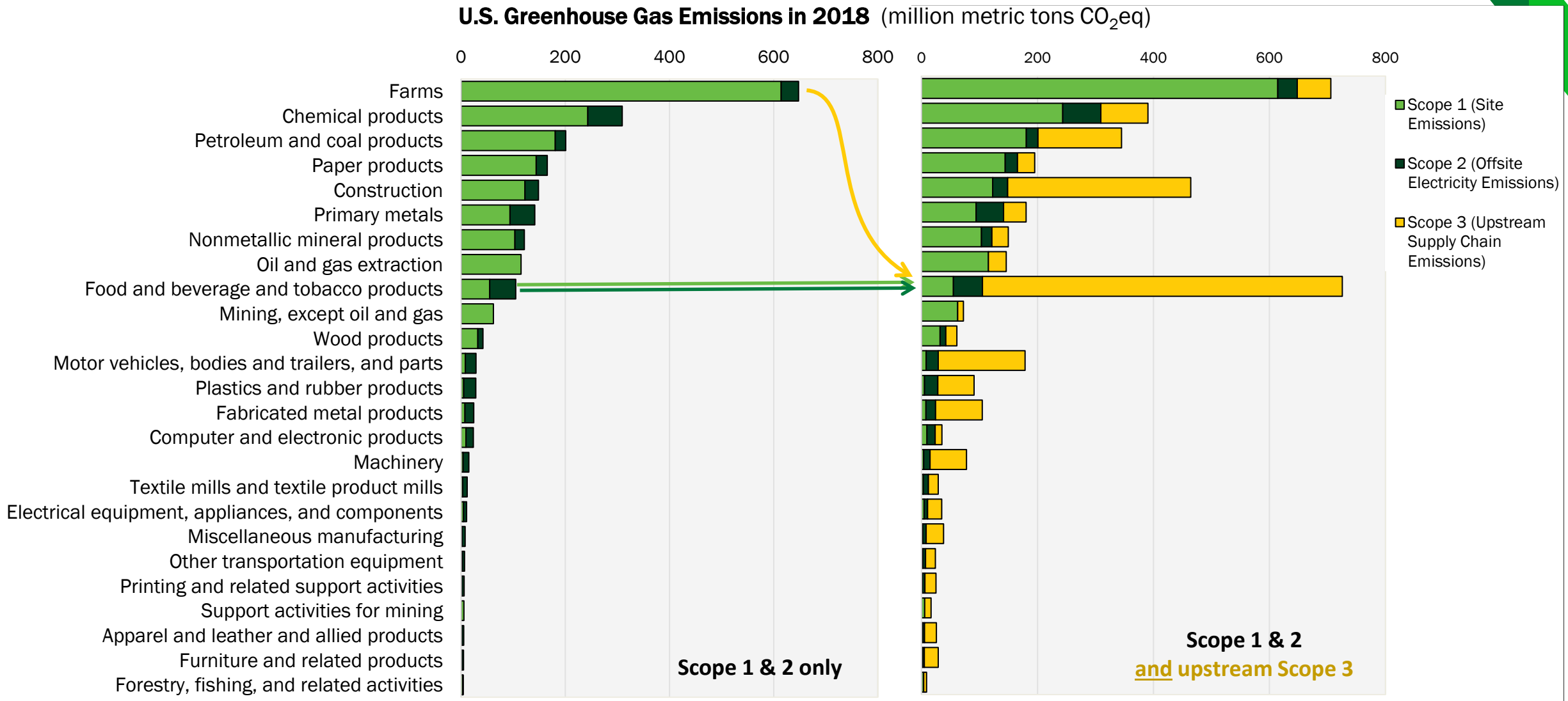


106
MMT CO_2e
Scope 1 & 2 only



741
MMT CO_2e
Scope 1 & 2
and upstream Scope 3

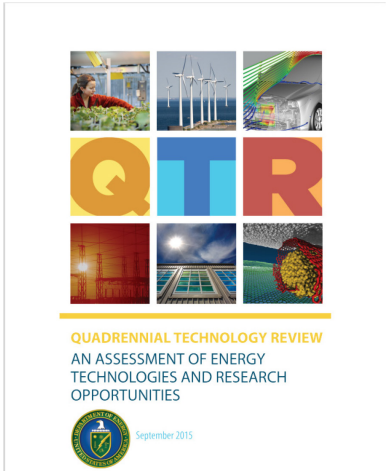
GHG Emission in Context: Significance of Supply Chain Emissions

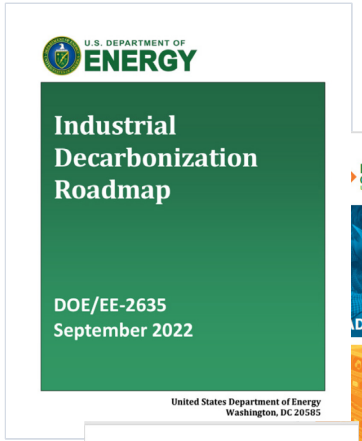


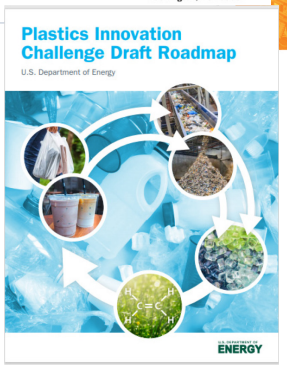
Data Source: DOE EEIO-IDA tool

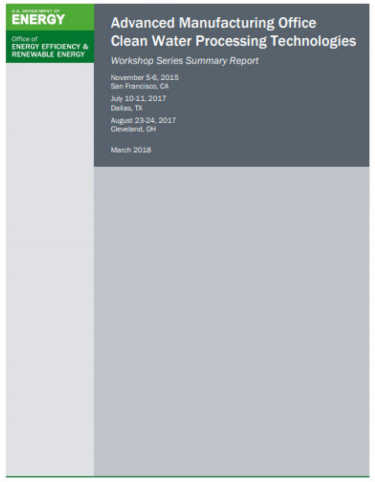
For more information, see Strategic Analysis poster on the EEIO-IDA tool

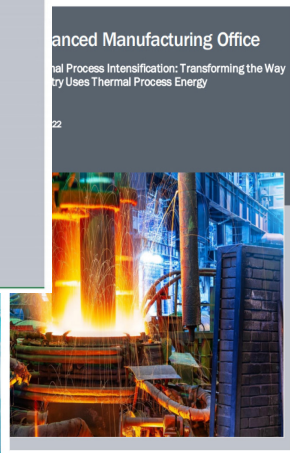
Strategic Analysis = Strategic Communications

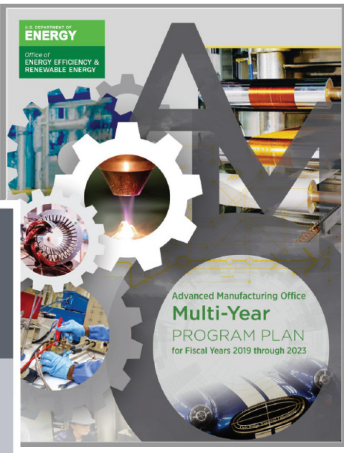












Foundational
- Technology Assessments
- Energy & Carbon
- Technology Adoption

Roadmaps
- Decarbonization
- Energy Storage
- Critical Materials
- Circular Economy

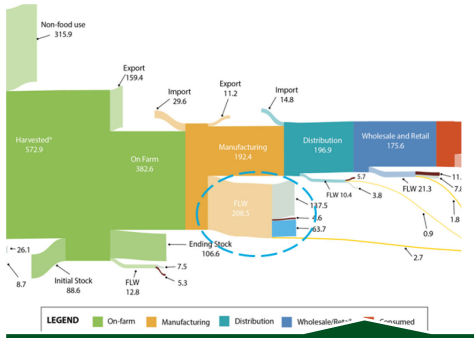
Workshops
- Energy Storage
- Critical Materials
- Thermal Intensification
- Ind. Heat Shot

Planning
- FOAs
- Prizes
- WFD Programs
- MYPP
- Big Ideas Summit
- Goal setting

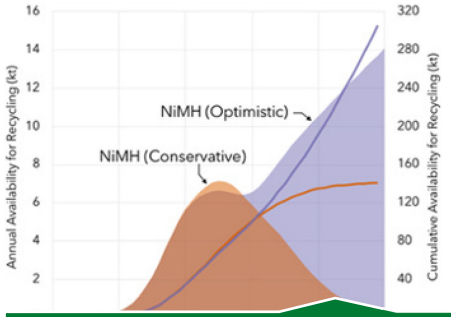
Portfolio
- Peer Review
- Annual Report
- Introspective
- Technology Tracking
- TEA/LCA

Conferences, journal articles etc.

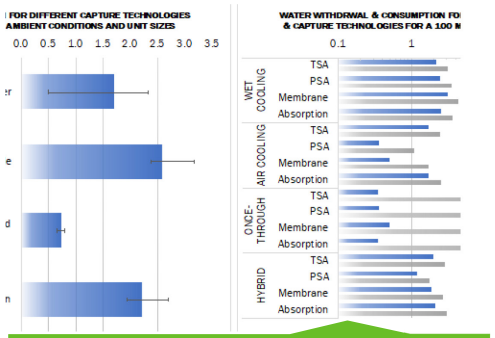
https://www.energy.gov/eere/iedo/energy-analysis-data-and-reports



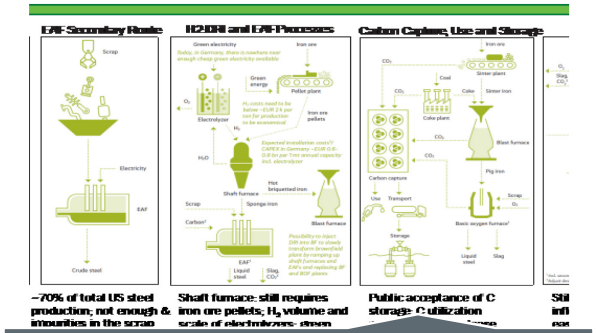
Energy & Materials Resource Flows



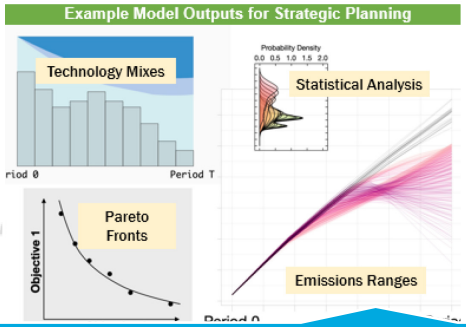
Sustainable & Circular Economy



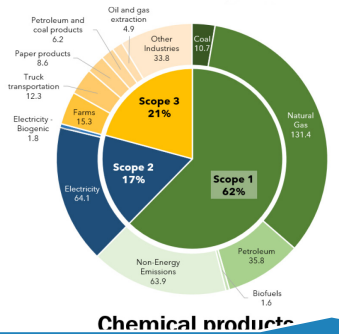
Water-Energy-Carbon Nexus



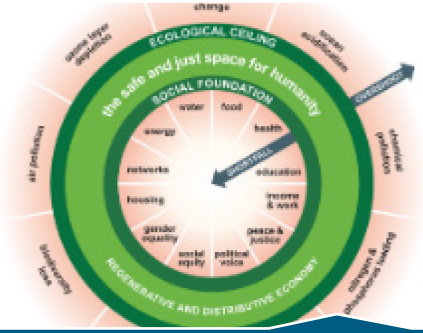
Industrial Decarbonization: Extended Pathways Analysis



Industrial Decarbonization: Integrated Systems & Deep Dives Analyses



Environmentally Extended Input-Output for Industrial Decarbonization Analysis



Project & Portfolio Impact & Environmental Justice Analysis

IEDO Strategic Analysis Team

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For additional information:
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Thank you