Agenda

- How analysis informs strategy: IEDO Strategic Analysis
- IEDO Strategic Analysis in context
- Examples on how previous, current, & future Strategic Analysis informs IEDO

  Industrial decarbonization roadmap, modeling & related efforts

- FY23 Strategic Analysis high-level view

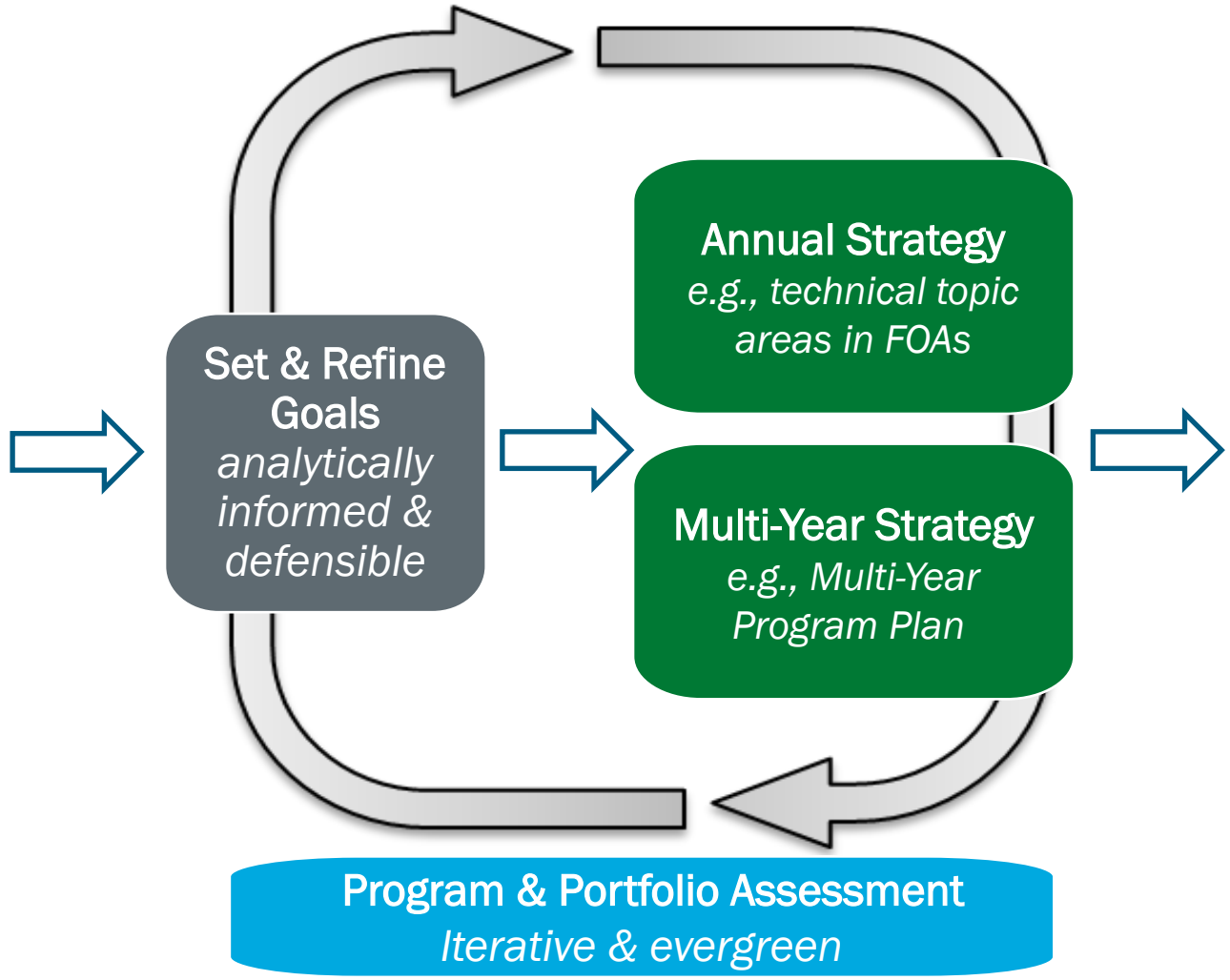
  See Strategic Analysis Posters for more details!

Strategic Analysis Informs 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

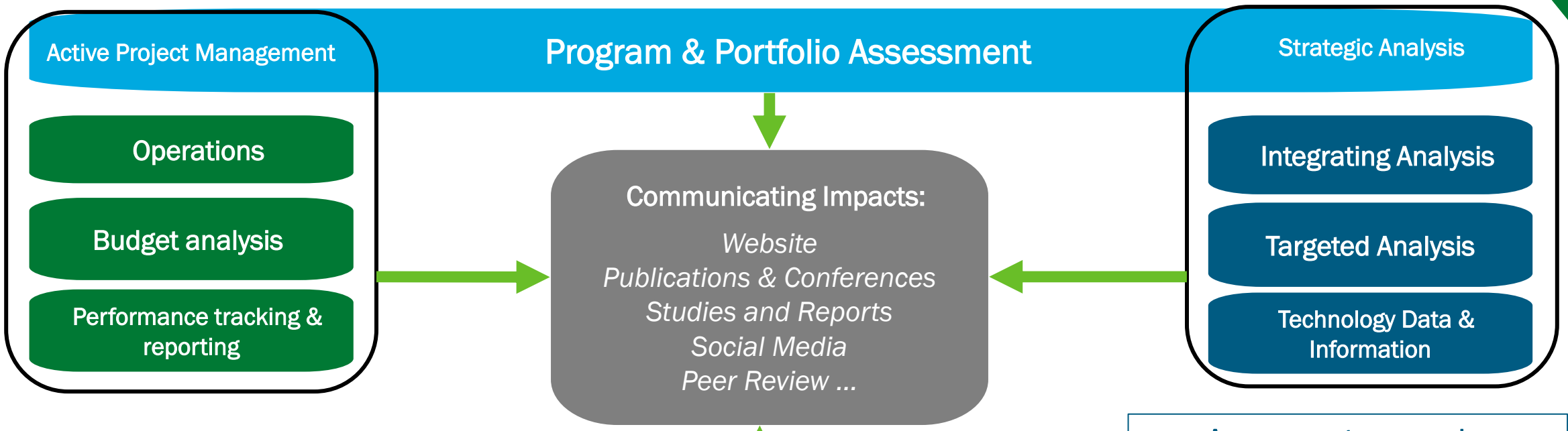


Desired Outcomes:
Well-informed IEDO Strategy & Planning and

- *DOE thought leadership*
- *Cross-agency recognition*
- *National & global impact*

* *Life cycle analysis/Technoeconomic analysis*

Strategic Analysis in Context with IEDO



Basic Project Information:
Necessary but insufficient

Project Information	*Quarterly Reports*
Merit Review Presentations	*Milestone Tracking*
Final Reports	*Budget Updates*

What do we need to know:
Impact of investments

- ~~Energy Impact?~~
- Emissions Impact?
- Economic Impact?

Assessment approach:
Utilize retrospective, introspective and prospective analysis methods

Goal – A more complete picture of project/portfolio impacts:

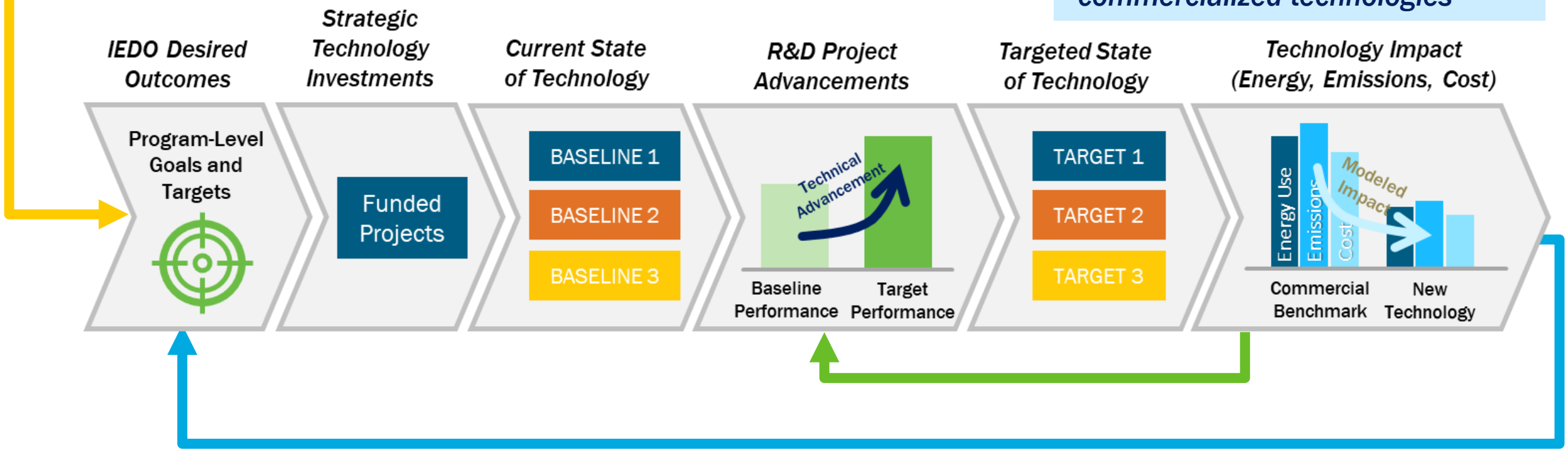
- Quantitative
- Measurable
- Aligned with DOE/IEDO program goals

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



Strategic Analysis in Context with DOE

An holistic top-down and bottom-up systems approach to
shape the IEDO portfolio with the highest potential for impact

DOE Priority Areas Examples

- ....
- Decarbonization
- Critical Materials
- Circular Economy
- Storage
- Water
- ....

Fundamental Analysis Elements

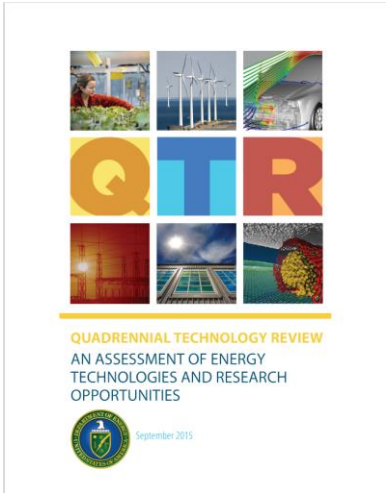
- Data, Tools, Methodologies
- Fundamental Systems Analyses (e.g., LCA, TEA)
- Integrating Approaches

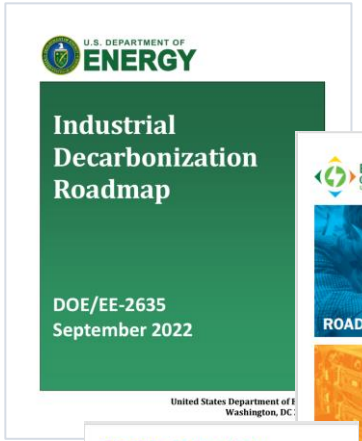
Bringing institutional knowledge to the table, IEDO is well-positioned to be functional and thought leaders in DOE.

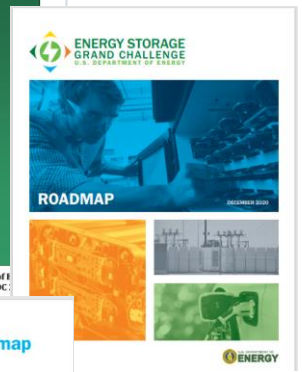
IEDO Technology Areas Examples

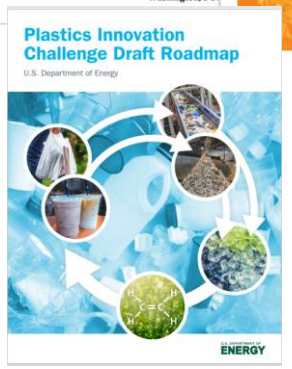
- ....
- Energy/ Emissions-Intensive subsectors
- Energy efficiency
- Low Carbon Fuels, Feedstocks, Energy Sources
- Thermal Processes
- Water/ Wastewater Energy/ Emissions
- Emerging Techs
- Industrial Electrification
- ....

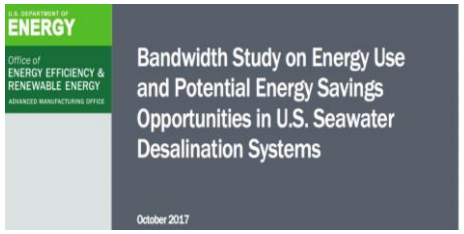
Strategic Analysis = Strategic Communications

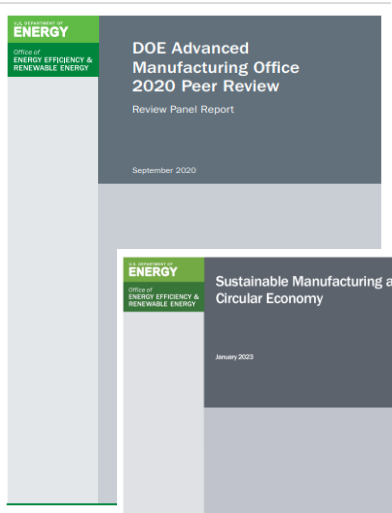


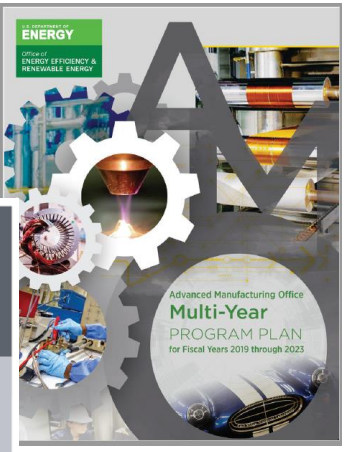












Foundational
- Technology Assessments
- Energy & Carbon
- Technology Adoption

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

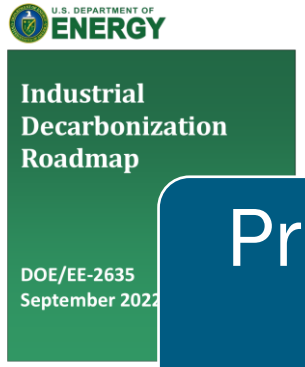
Workshops
- Energy Storage
- Critical Materials
- Thermal Intensification
- Ind. Heat Shot

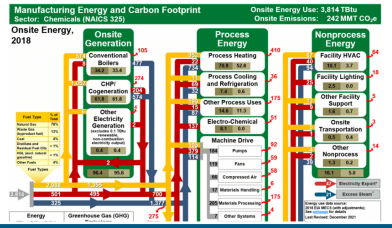
Planning
- FOAs
- Prizes
- WFD Programs
- MYPP
- Big Ideas Summit
- Goal setting

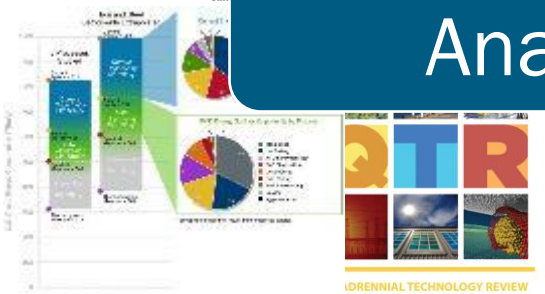
Portfolio
- Peer Review
- Annual Report
- Introspective
- Technology Tracking
- TEA/LCA

Conferences, journal articles etc.

Previous, current, future work supports IEDO planning







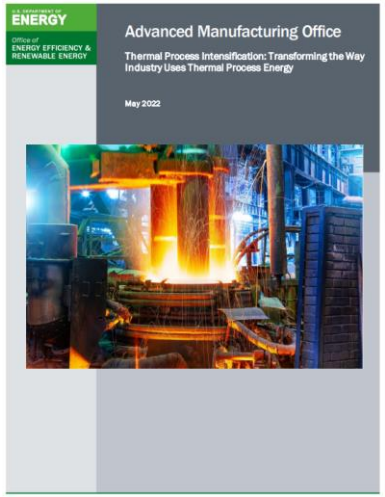
Previous (AMO) Strategic Analysis

Current Analysis

Future Analysis (FY24+)

IEDO analytically supported baselines, targets, & metrics

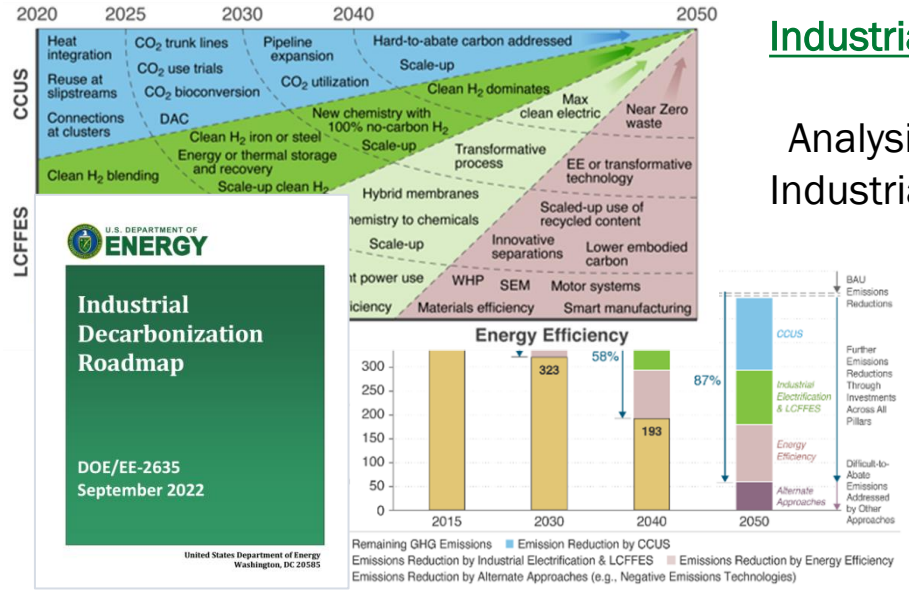
Expertise informs analyses and initiatives – e.g., thermal



Thermal Process Intensification (TPI)

Input from subject-matter experts on transformative technologies and strategies to substantially improve the performance of thermal processing systems in the industrial sector.

- Workshop in late 2020
- Report published in May 2022

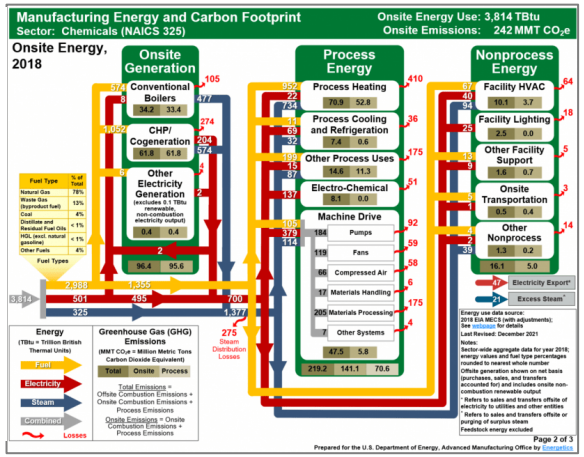


Industrial Decarbonization Roadmap

Analysis associated with Industrial Decarbonization Roadmap

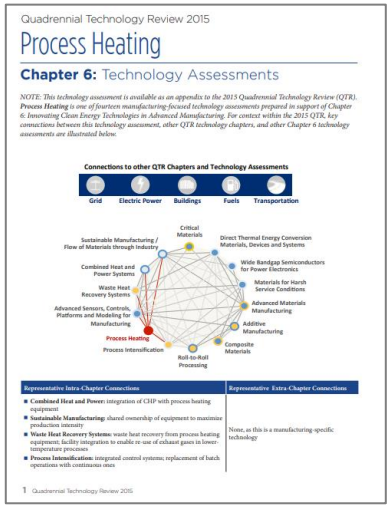
Manufacturing Energy and Carbon Footprints

The flow of energy supply, demand, and losses as well as greenhouse gas (GHG) emissions for end uses in 15 U.S. manufacturing industries and manufacturing-wide.



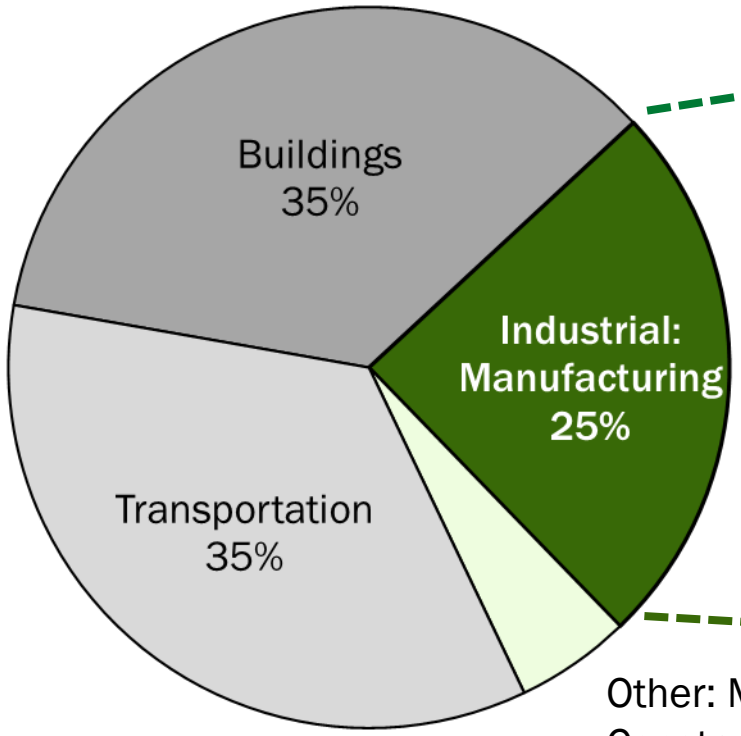
DOE Quadrennial Technology Review 2015

Technology assessment on process heating



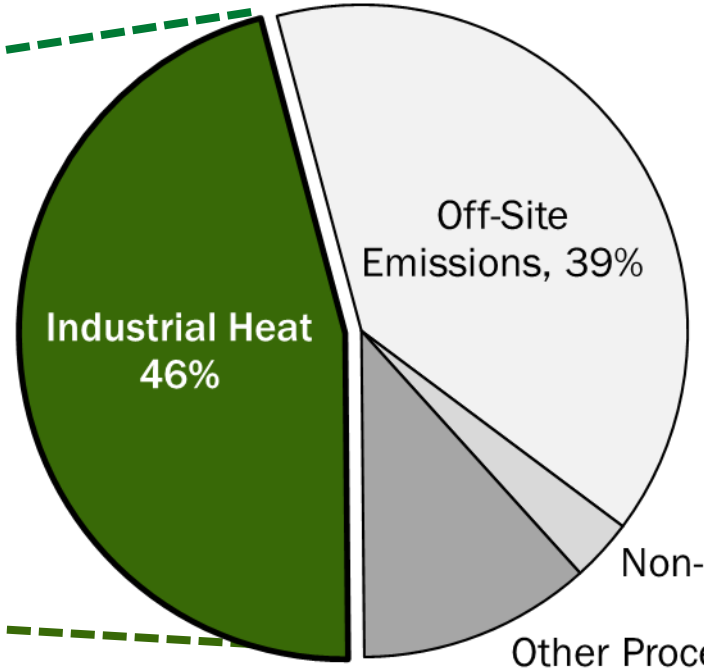
11% of All U.S. Energy-Related Emissions is from Process Heating

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



Other: Mining, Agriculture, Construction, 5%

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



Non-process Use, 3%

Other Process Use, 12%

- Electrification
- Nuclear
- Solar Thermal
- Hydrogen
- Biomass
- Fossil + CCUS

Opportunity for improved energy productivity and reduced emissions

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

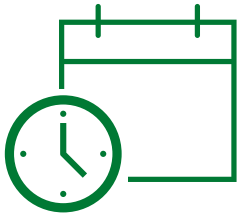
DOE Industrial Heat Shot

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

Timed with 2035 Clean Grid Goal.

https://www.energy.gov/eere/industrial-heat-shot

Previous, current, future work supports IEDO planning

Previous (AMO) Strategic Analysis

Current Analysis

Future Analysis (FY24+)

IEDO analytically supported baselines, targets, & metrics

Highlights from Current Analysis Topics

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

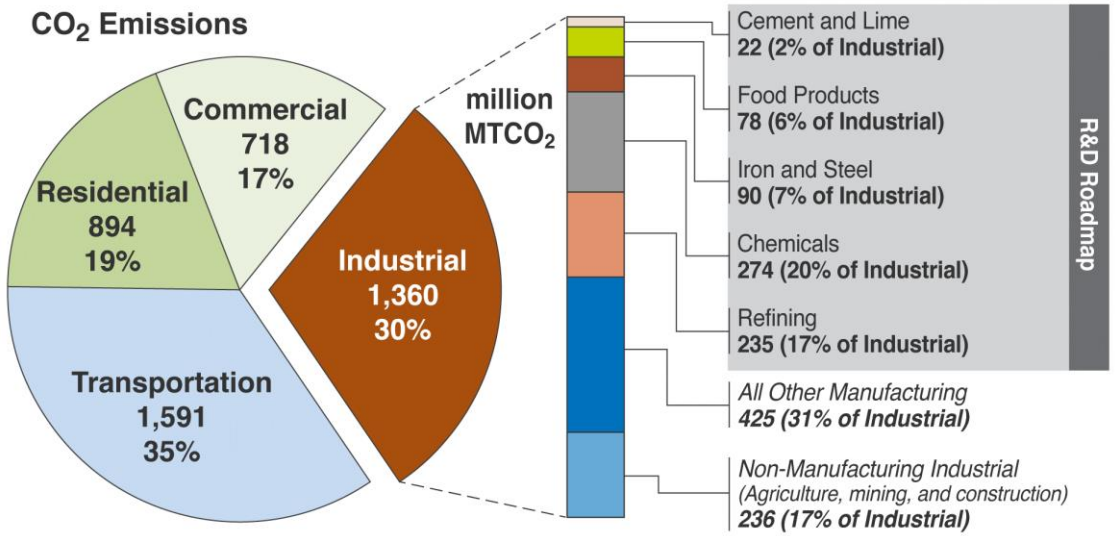
- Industrial modeling & pathways analysis
- Deep dives & analysis of roadmap pillar technologies
- Demand side materials (commodities) efficiency strategies
- Process optimization & intensification technologies

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

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

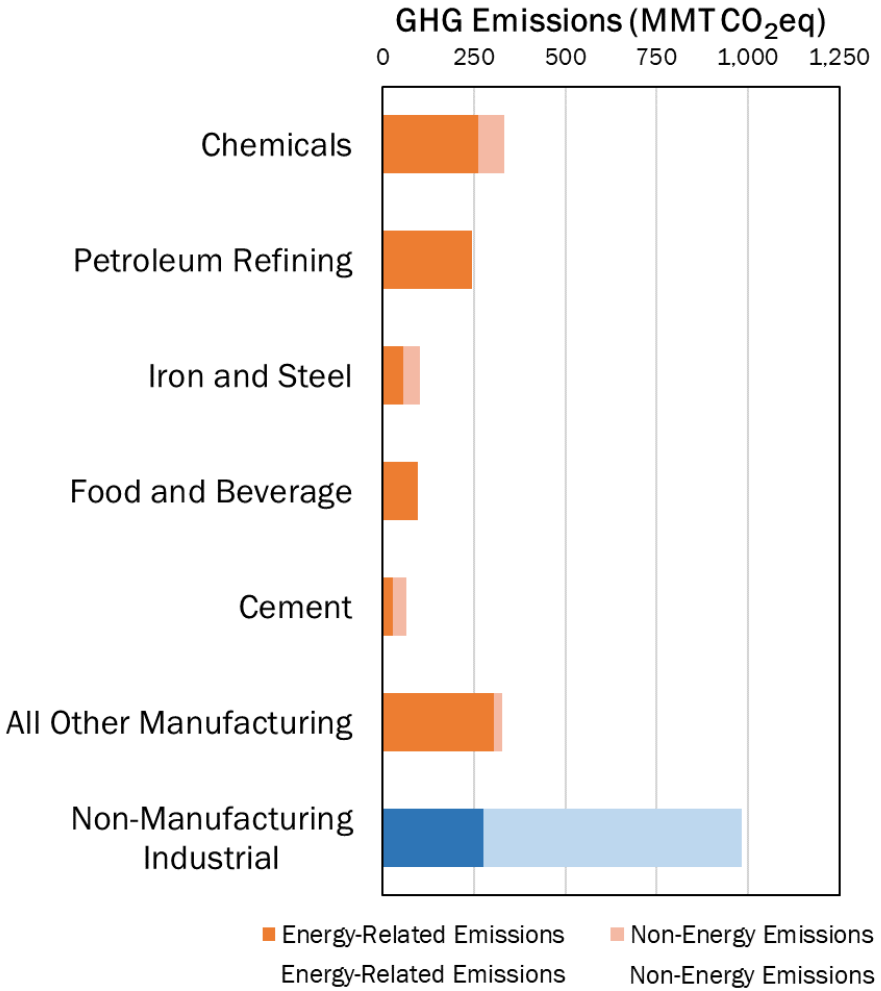
ACCOUNTS FOR **30%** of energy-related CO_2 emissions

Energy-Related CO_2 emissions, 2020
(million metric tons)



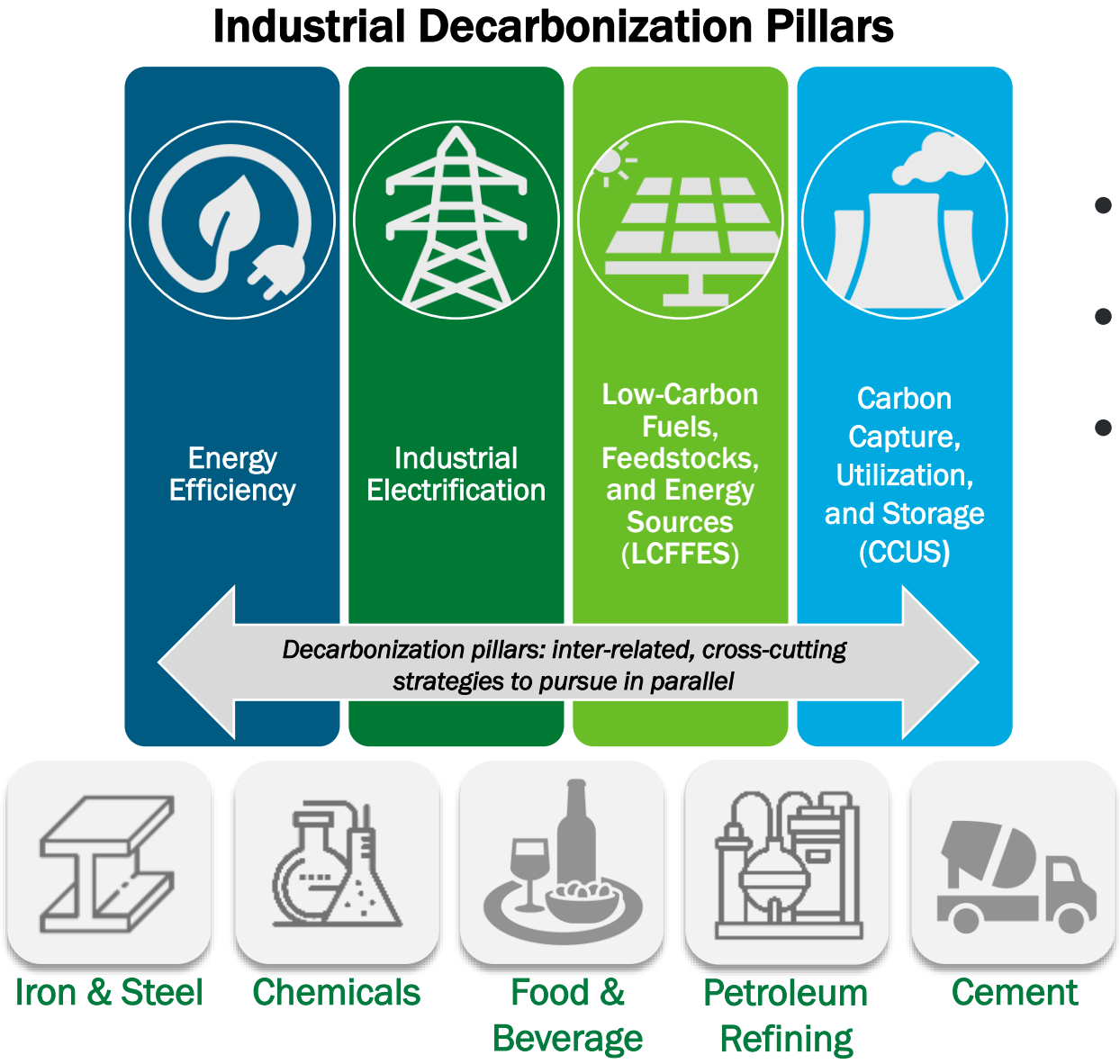
EIA, *Annual Energy Outlook 2020 with Projections to 2050*. Source: Industrial Decarbonization Roadmap.

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



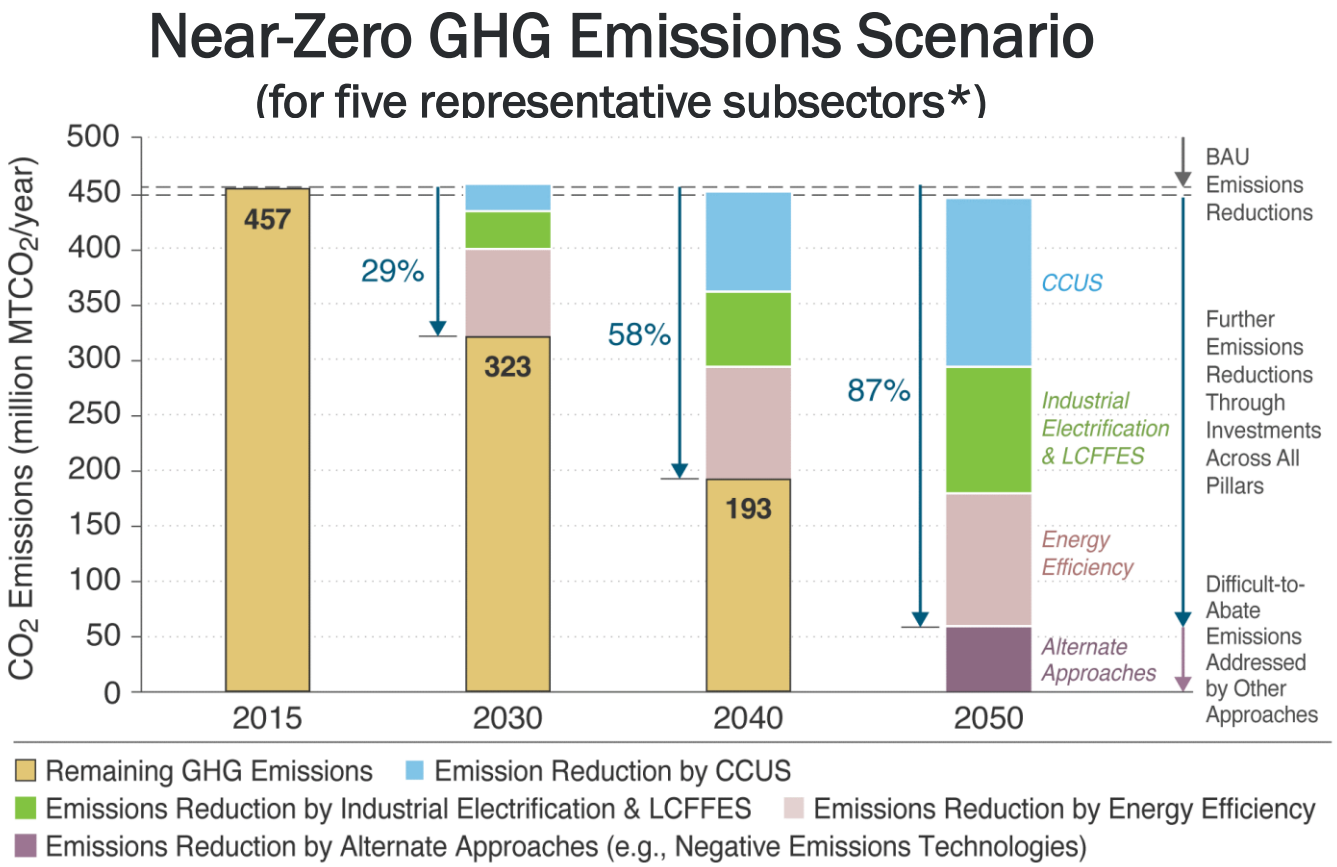
EIA Monthly Energy Review, Manufacturing Energy Consumption Survey; EPA GHGRP Inventory

DOE Industrial Decarbonization Roadmap - Pillars and Sector Focus Areas



- Invest in all pillars
- Leverage cross-sector approaches
- Interdependencies require systems solutions

2050 Industrial Emissions Reductions Potential



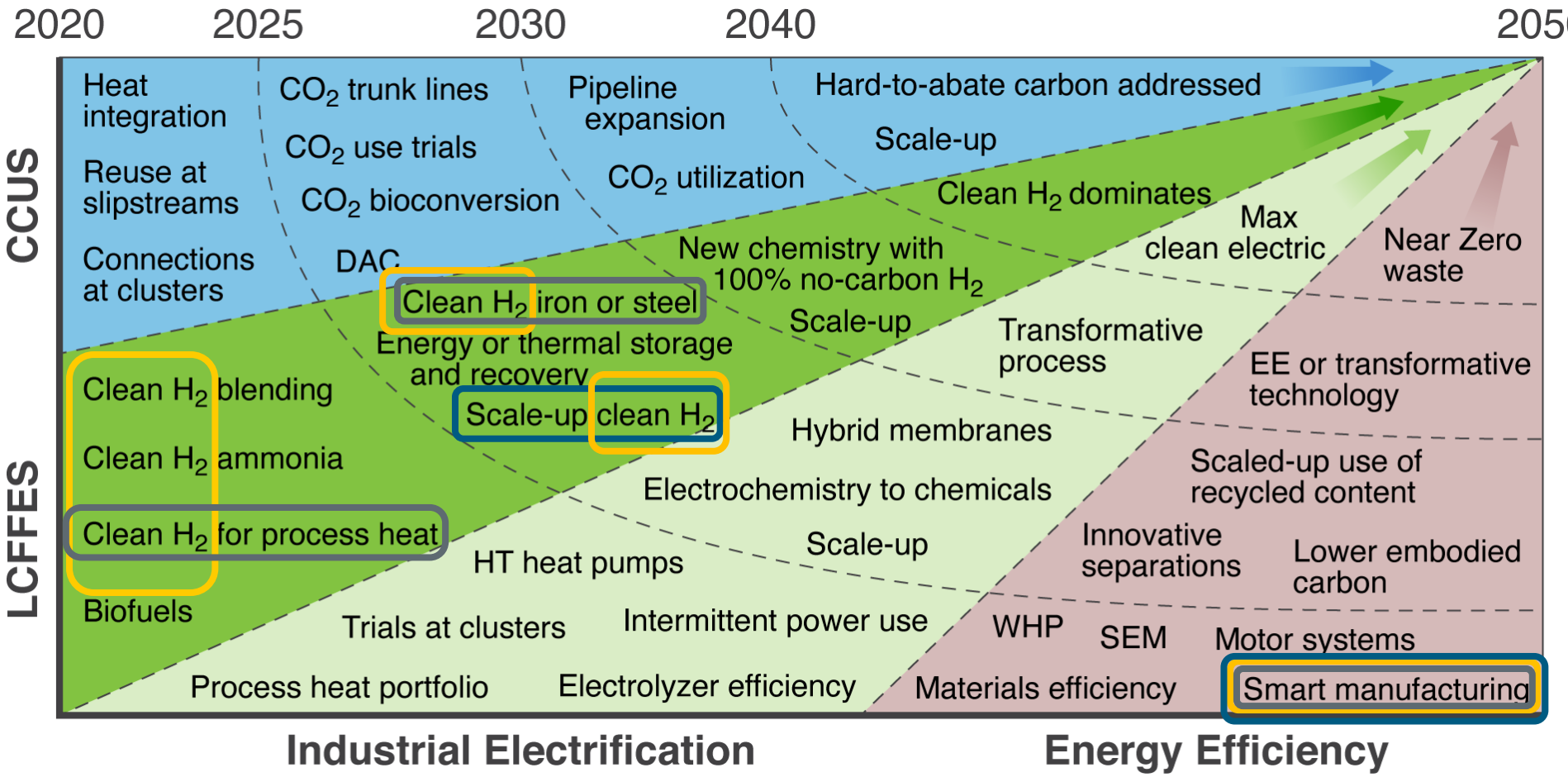
Roadmap Recommendations

- 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

Industrial Decarbonization is also a systems challenge



Industrial GHGs require approaches at multiple levels:

- Core process
- Facility
- Beyond plant bounds

What are the implications of:

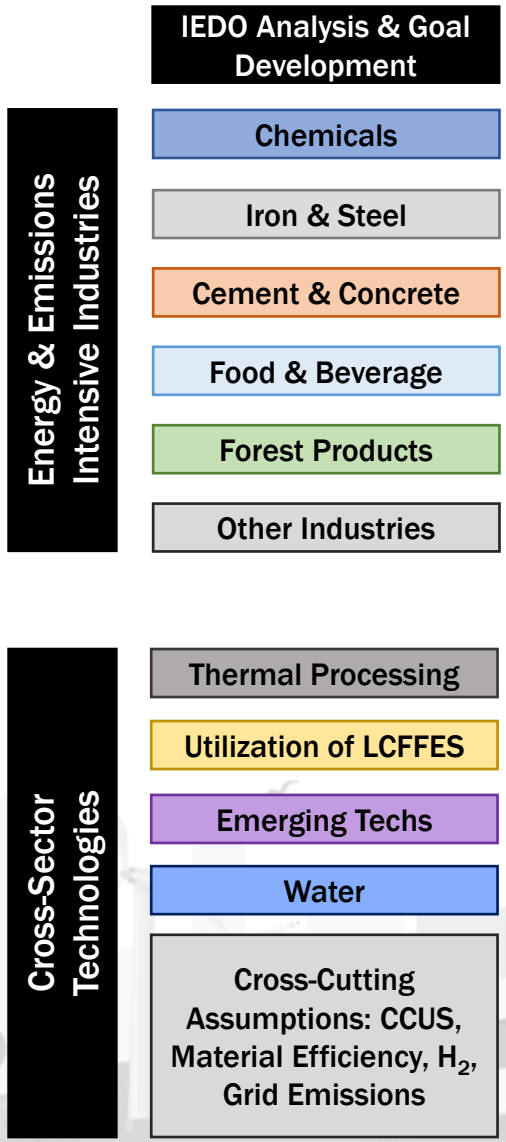
- Expanded H_2 generation & use
- New thermal energy sources & systems
- Smart manufacturing, automation, & data analytics
- Transition to clean electricity
- Policies

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

Source: Industrial Decarbonization Roadmap

Current Industrial Decarbonization Analysis and Goal Development Efforts in IEDO



Industrial Decarbonization Modeling

- **Expanded bottom-up analysis** to capture specific technologies or process units
- Identify and standardize inputs and assumptions for **transparency now**, and **future-proofing** going forward
- **Add resolution** - fuel sources, process emissions, and adoption rates by technology, electrification, onsite generation, etc.
- **Refine pillar breakdown** calculations to more accurately capture adoption of technologies and separate electrification from low carbon fuels, feedstocks, & energy sources (LCFFES)

Buying Clean requires Making it Clean

NREL Transforming ENERGY

energetics Clean Energy Consulting

BERKELEY LAB Lawrence Berkeley National Laboratory

Materials Flow through Industry (MFI) Tool
Linear network model of the U.S. industrial sector. It can model a range of manufacturing scenarios, including the effects of changes in production technology and increases in industrial energy efficiency.

https://www.nrel.gov/manufacturing/mfi-modeling-tool.html

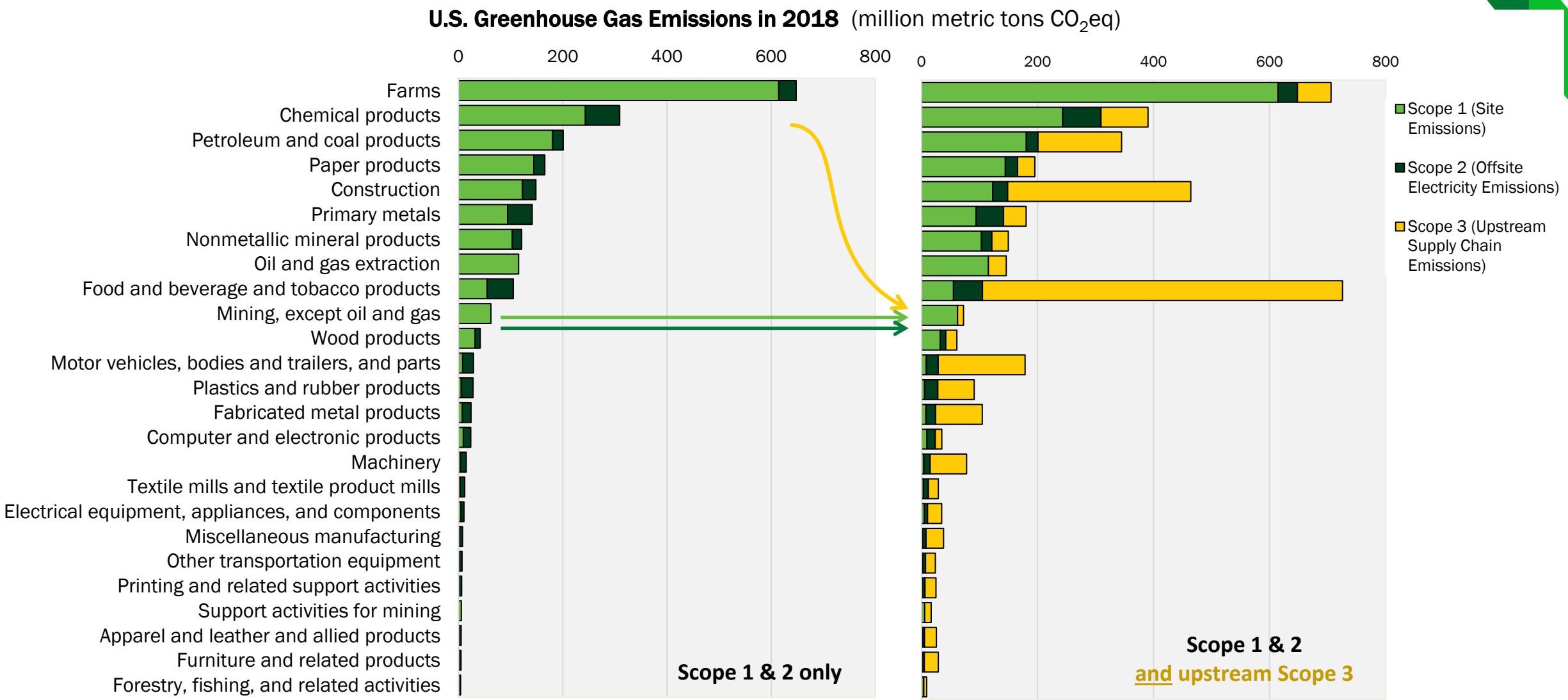
Environmentally-Extended Input/Output (EEIO) models
Input/output techniques to estimate the total impact of an industry's products on environmental metrics, such as greenhouse gas emissions.

LIGHTEn-UP Tool
Scenario framework for assessing prospective net energy impacts of a technology/product, accounting for both manufacturing and end-use life cycle phases.

https://energyanalysis.lbl.gov/tools

LIGHTEn-UP: Lifecycle Industry GreenHouse gas, Technology and Energy through the Use Phase

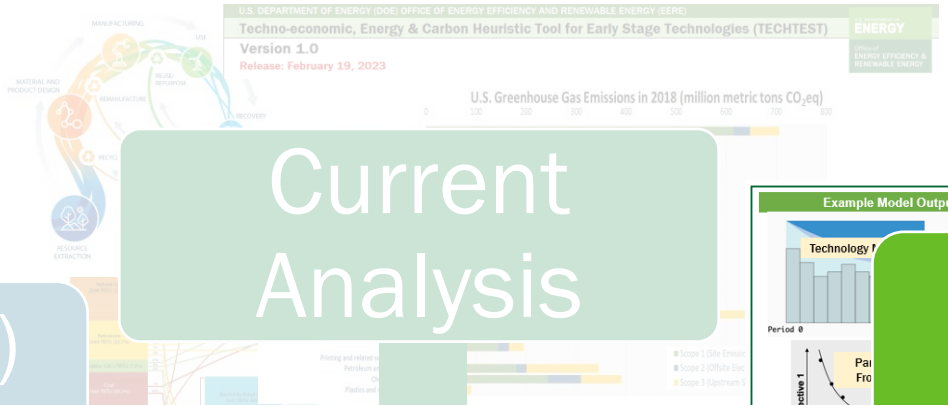
GHG Emission in Context: Significance of Supply Chain Emissions

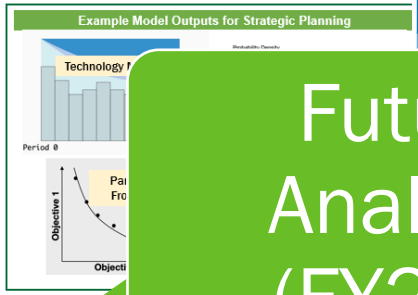


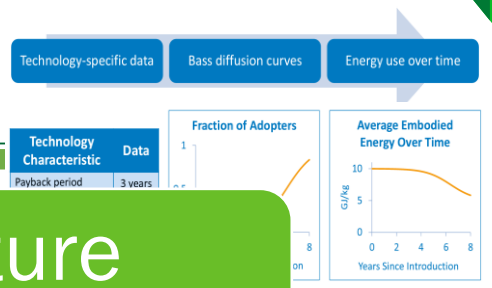
Data Source: DOE EEIO-IDA tool

For more information, see Strategic Analysis poster on the EEIO-IDA tool (Tuesday 5/16)

Previous, current, future work supports IEDO planning







Previous (AMO) Strategic Analysis

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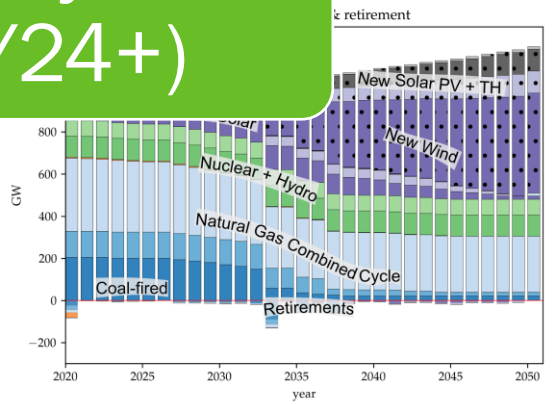


IEDO analytically supported baselines, targets, & metrics

The imperatives for U.S. industrial decarbonization

Incremental solutions are insufficient:

- The need for an industrial re-revolution

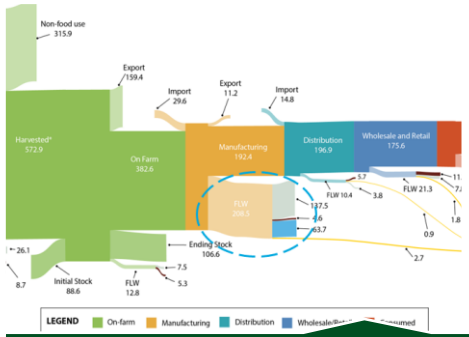
CO_2 emissions from inefficient materials flows are a problem:

- The opportunity for more thoroughly efficient production processes

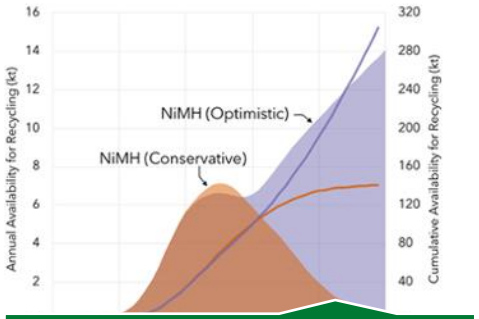
GHGs are one environmental impact factor:

- The need for more thoroughly sustainable manufacturing

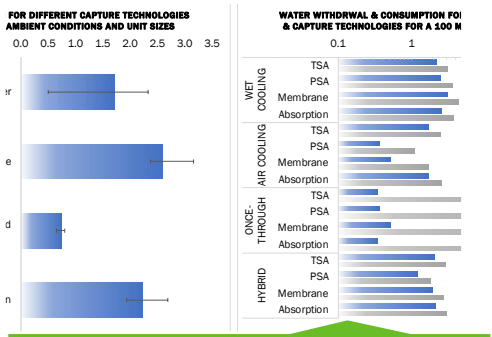
Want to Learn More? See the Strategic Analysis Posters!



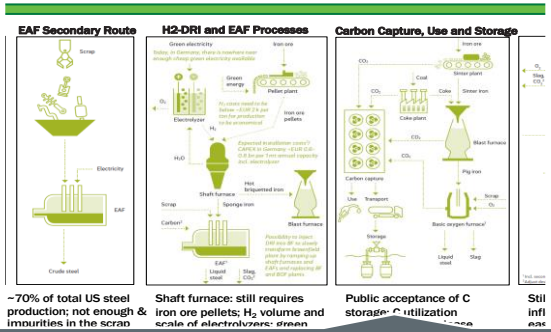
Energy & Materials Resource Flows



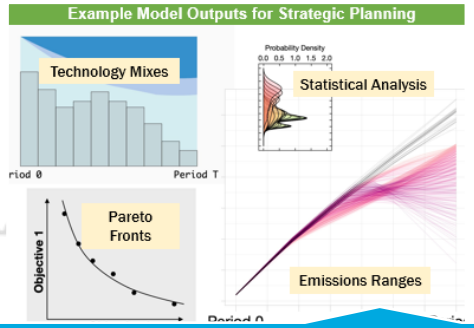
Sustainable & Circular Economy



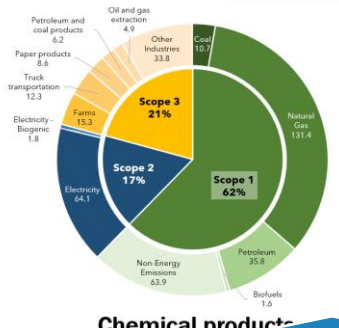
Water-Energy-Carbon Nexus



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

Closing Thoughts

Technology Investment Portfolios

- Investment strongly influences outcomes
- Too much diversification is a bad strategy
- It is essential to make targeted investments
- Should put a few eggs in the right baskets

ELSEVIER

Journal of Economic Dynamics and Control

Volume 101, April 2019, Pages 211-238

Wright meets Markowitz: How standard portfolio theory changes when assets are technologies following experience curves

Rupert Way [a b], François Lafond [a b c], Fabrizio Lillo [d e], Valentyn Panchenko [f], J. Doyne Farmer [a g h]

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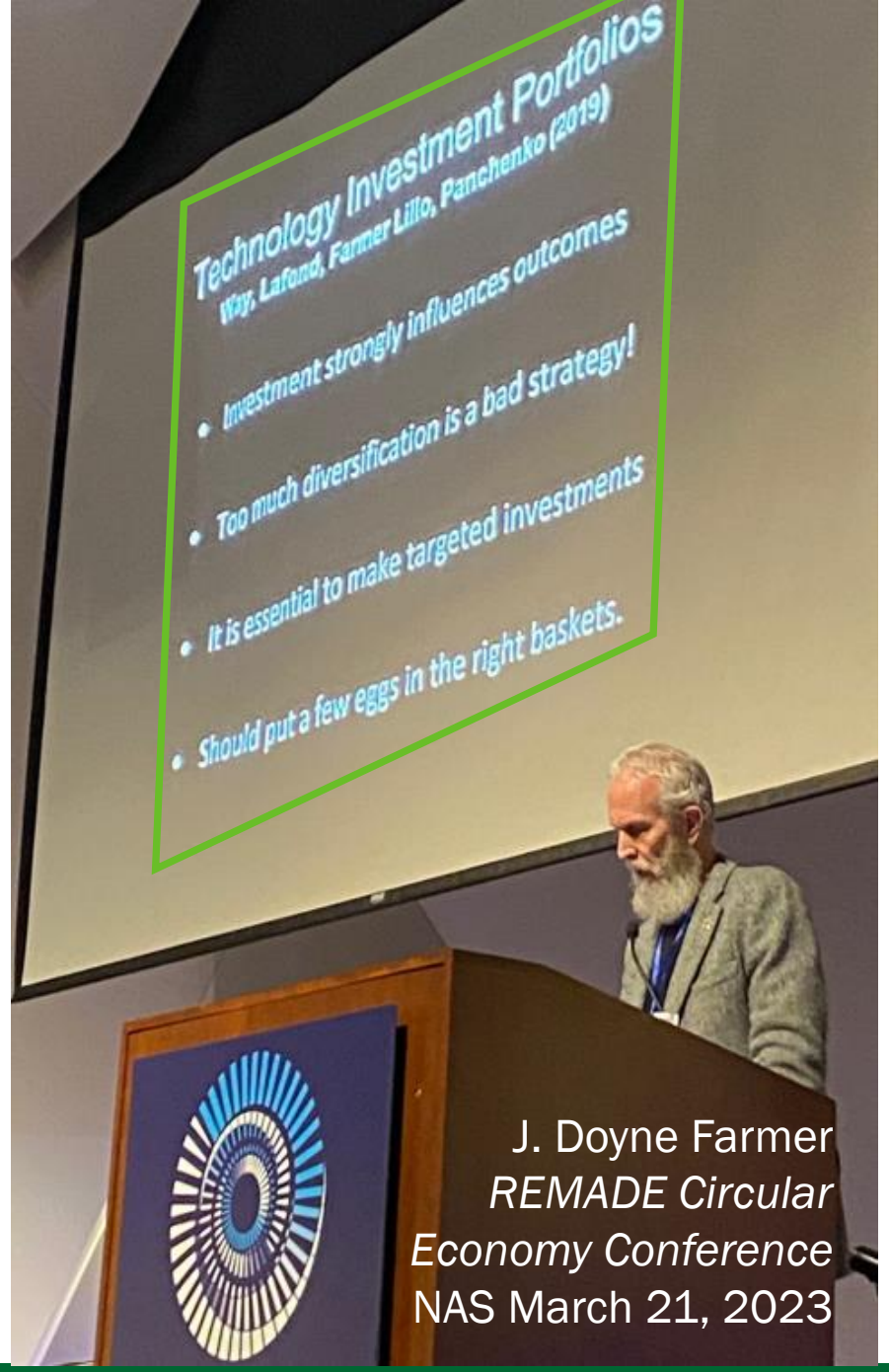

J. Doyne Farmer
REMADE Circular Economy Conference
NAS March 21, 2023

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

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ORNL – Sachin Nimbalkar, Kristina Armstrong, Prashant Nagapurkar, Kiran Thirumaran, Ikenna Okeke, Dipti Kamath

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DOE – Zach Pritchard

Thank you