U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

Industrial Technology Innovation Advisory Committee Meeting

August 28, 2024

2 pm – 4 pm ET

Virtual (ZoomGov)

We will start momentarily...

Meeting Recording Announcement

This Zoom call, including all audio and images of participants and presentation materials, may be recorded, saved, edited, distributed, used internally, posted on DOE's website, or otherwise made publicly available. If you continue to access this call and provide such audio or image content, you consent to such use by or on behalf of DOE and the Government for Government purposes and acknowledge that you will not inspect or approve, or be compensated for, such use.

Housekeeping Reminders

- General audience does not have the ability to unmute and/or turn on camera during this presentation.
- The chat has been disabled.
- Public comments:
  - The deadline for submitting public comments to share during this meeting was 5:00 pm EDT on August 26.
  - You may send a written statement to ITIAC@ee.doe.gov

ITIAC Nominations

- DOE is continually seeking ITIAC nominations for consideration for future membership vacancies and to maintain balance in points of view
- Submissions should include the nominee's name, resume, biography, and any letters of support
- Committee members are appointed for a two-year term and may be reappointed for up to two successive terms
- Submit nominations/questions to ITIAC@ee.doe.gov

See website for more details: https://www.energy.gov/eere/iedo/industrial-technology-innovation-advisory-committee#candidates

Welcome & Opening Remarks

Sharon Nolen
ITIAC Chair
Eastman Chemical

Dr. Zach Pritchard
Technology Manager
ITIAC Designated Federal Officer
Industrial Efficiency and
Decarbonization Office

Agenda – August 28, 2024 ITIAC meeting

Welcome and opening remarks	2:00 – 2:10 PM
Pathways to U.S. Industrial Transformations Introduction & Overview	2:10 – 2:40 PM
Pathways to U.S. Industrial Transformations Modeling & Draft Results	2:40 – 3:15 PM
Q&A and discussion	3:15 – 3:55 PM
~~Public comment~~ (none received)	~~3:45 – 3:55 PM~~
Conclusion	3:55 – 4:00 PM
Adjourn	4:00 PM

Mural board & questions

Enter questions or comments on the Mural board at any time.

Please feel free to raise your hand to ask questions during the meeting, or you can add to Mural board/hold until the discussion session.

Building a Net-zero, Clean Energy Future

The U.S. industrial sector (manufacturing, agriculture, mining, and construction) accounts for:

33% of the nation's primary energy use

30% of energy-related CO_2 emissions

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

17% energy-related CO_2 emissions increase*

Energy-Related CO_2 Emissions By Sector

*EIA, *Annual Energy Outlook 2021 with Projections to 2050*.

DOE Industrial Decarbonization Roadmap

Industrial Decarbonization Pillars

Energy Efficiency	Industrial Electrification	Low-Carbon Fuels, Feedstocks, and Energy Sources (LCFFES)	Carbon Capture, Utilization, and Storage (CCUS)

Decarbonization pillars: inter-related, cross-cutting strategies to pursue in parallel

Iron & Steel

Chemicals

Food & Beverage

Petroleum Refining

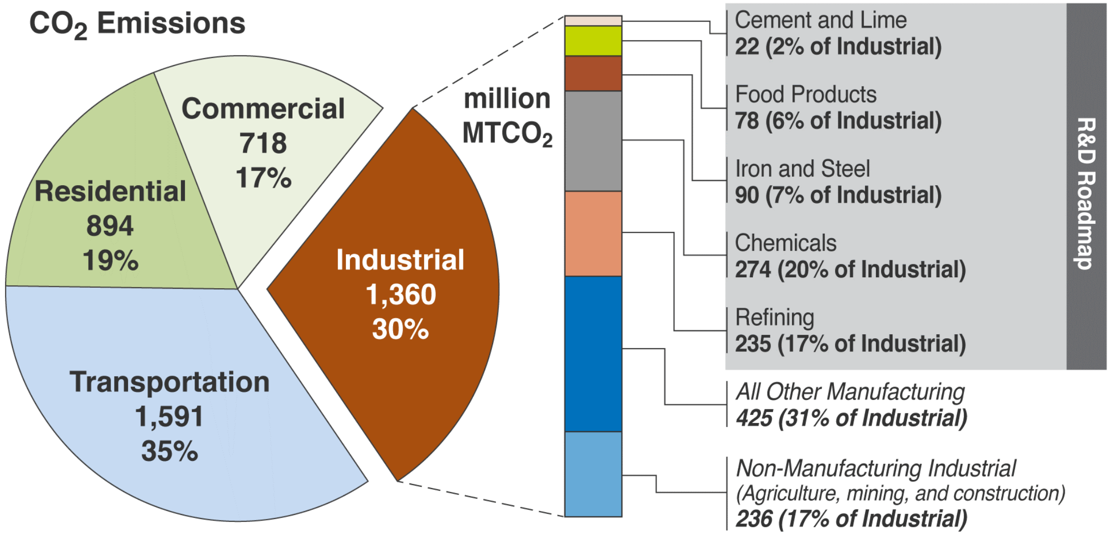
Cement

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

U.S. Industrial GHG Emissions

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

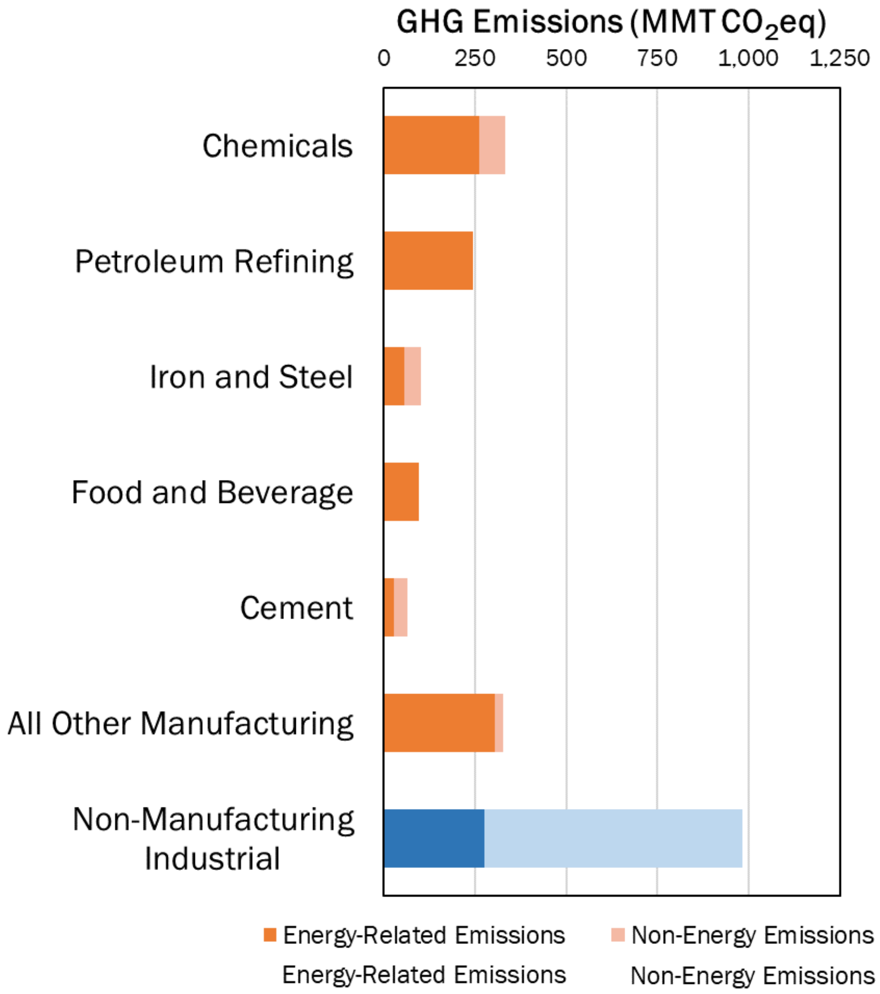
ACCOUNTS FOR **30%** of energy-related CO_2 emissions



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

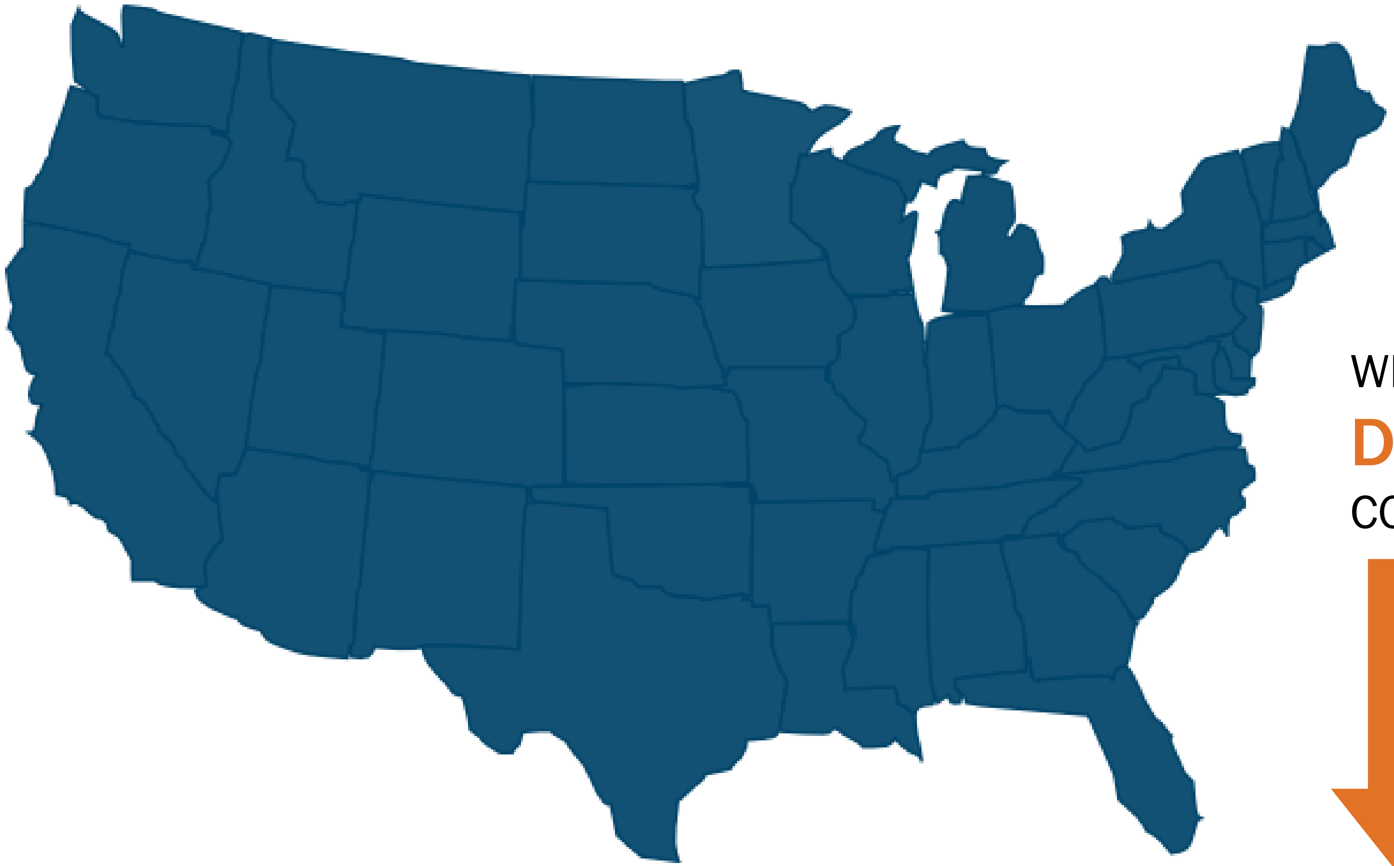
Decarbonizing Industry is an Opportunity for America's Economy

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
CO_2 emissions

38% of Total U.S. Greenhouse Gas Emissions

Systemic barriers to industrial decarbonization

Investment scale → In the range of

$700 Billion – 1.1 Trillion

just for 8 industrial sectors 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

Industrial Efficiency and Decarbonization Office (IEDO)

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

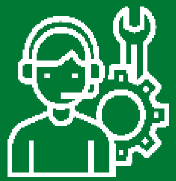
Energy- and Emissions-Intensive Industries

- 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**

$ Half billion over 2 years

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

Primary Challenges and Barriers to Industrial Decarbonization

Challenges

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.

Technology Readiness. ~60% of industrial emissions reductions will come from technologies that are nascent, non-competitive, or entirely unknown.

Systemic Challenge. Interconnectedness and opportunities for symbiosis between subsectors.

Ensure an Equitable Transition. Ensure just and equitable outcomes for all Americans during industry's transition to a clean energy economy.

Barriers

Costs and Value. Of developing and deploying existing and emerging decarbonization technologies.

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

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

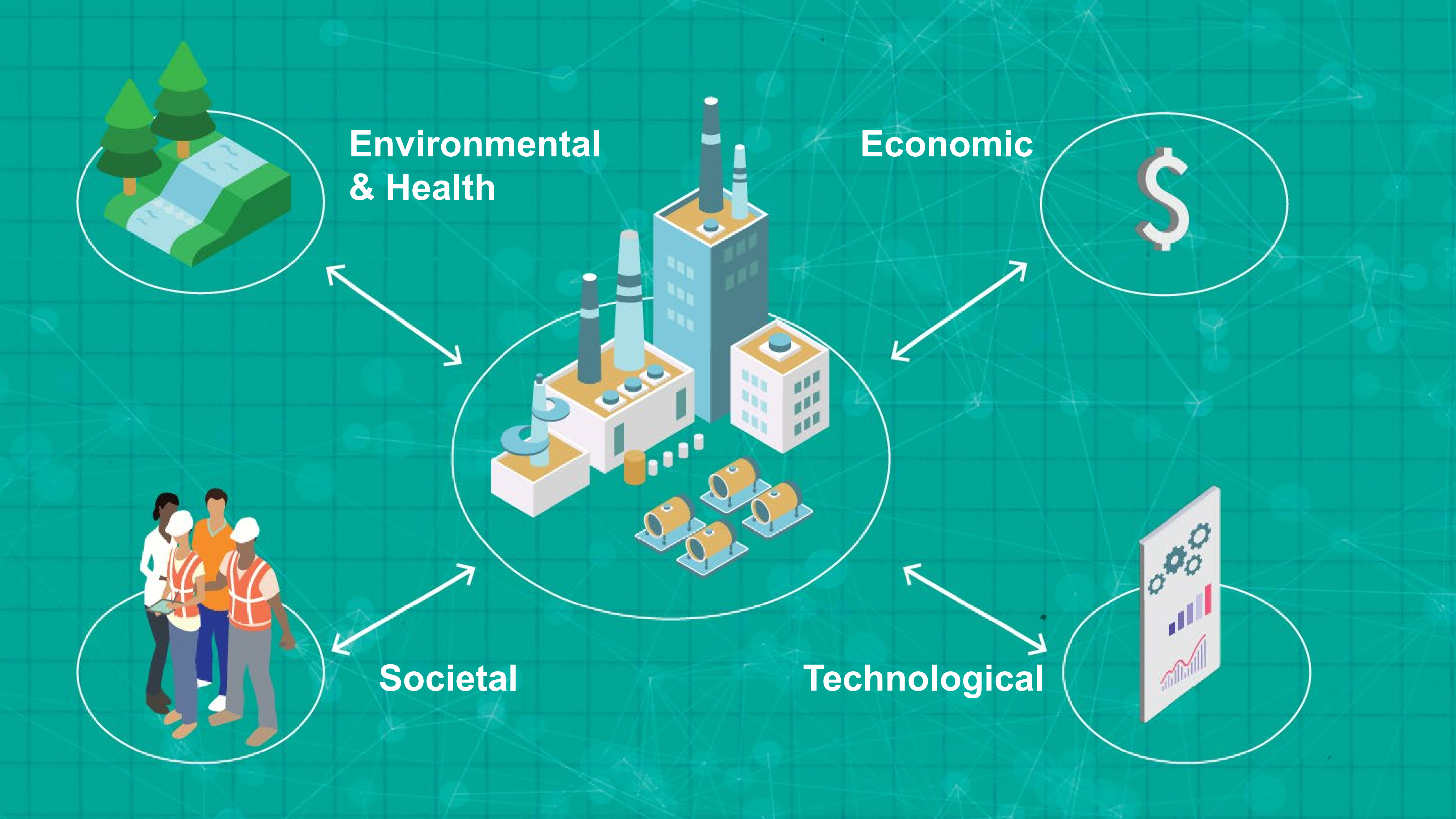
Inefficient Information Flows. Data privacy concerns and lack of information sharing can impact the scale and speed of industrial decarbonization efforts.

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

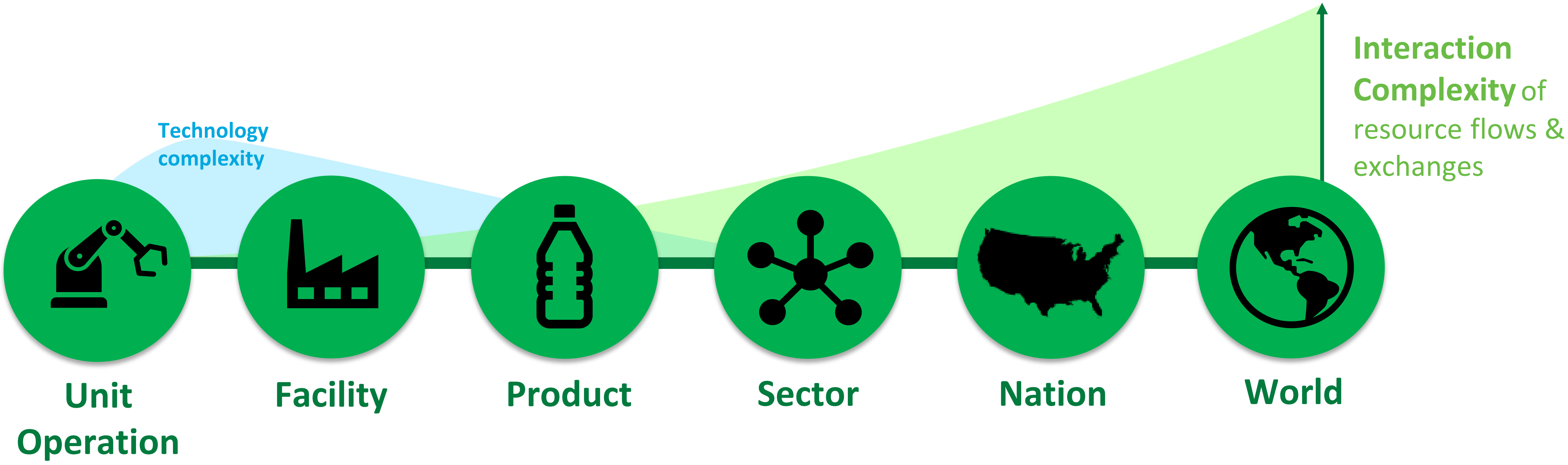
- Direct and indirect CO_2 emissions.
- Criteria air pollutants, toxics, other air and water pollutants, waste, thermal pollution, and land use.
- Associated health impacts.

- 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.

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

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

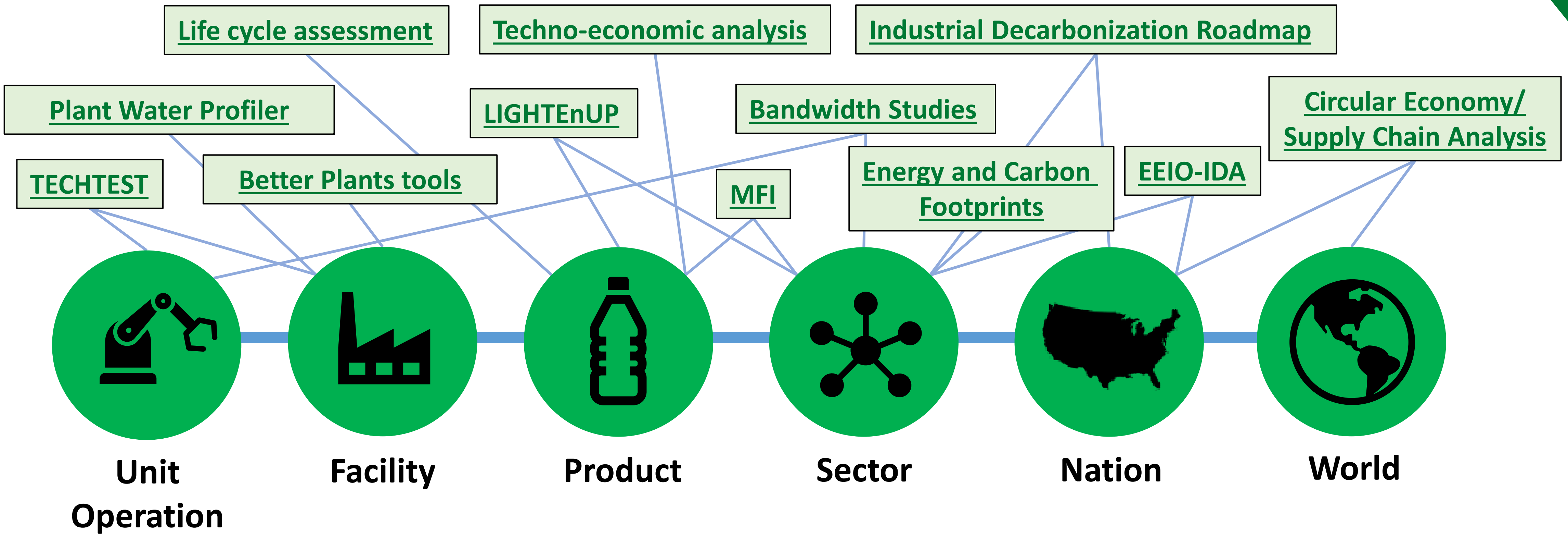
Understanding Industrial Impacts and Complex Interactions



- **What** are (collective) anticipated impacts?
- **Where** will (collective) impacts occur?
- **When** will impacts occur?

Resources	Emissions	Economics
Water	Greenhouse gases	Exchange of goods
Materials	Toxic releases	
Fuels / Energy	**… and more**	

Understanding Industrial Impacts and Complex Interactions



Acronyms:

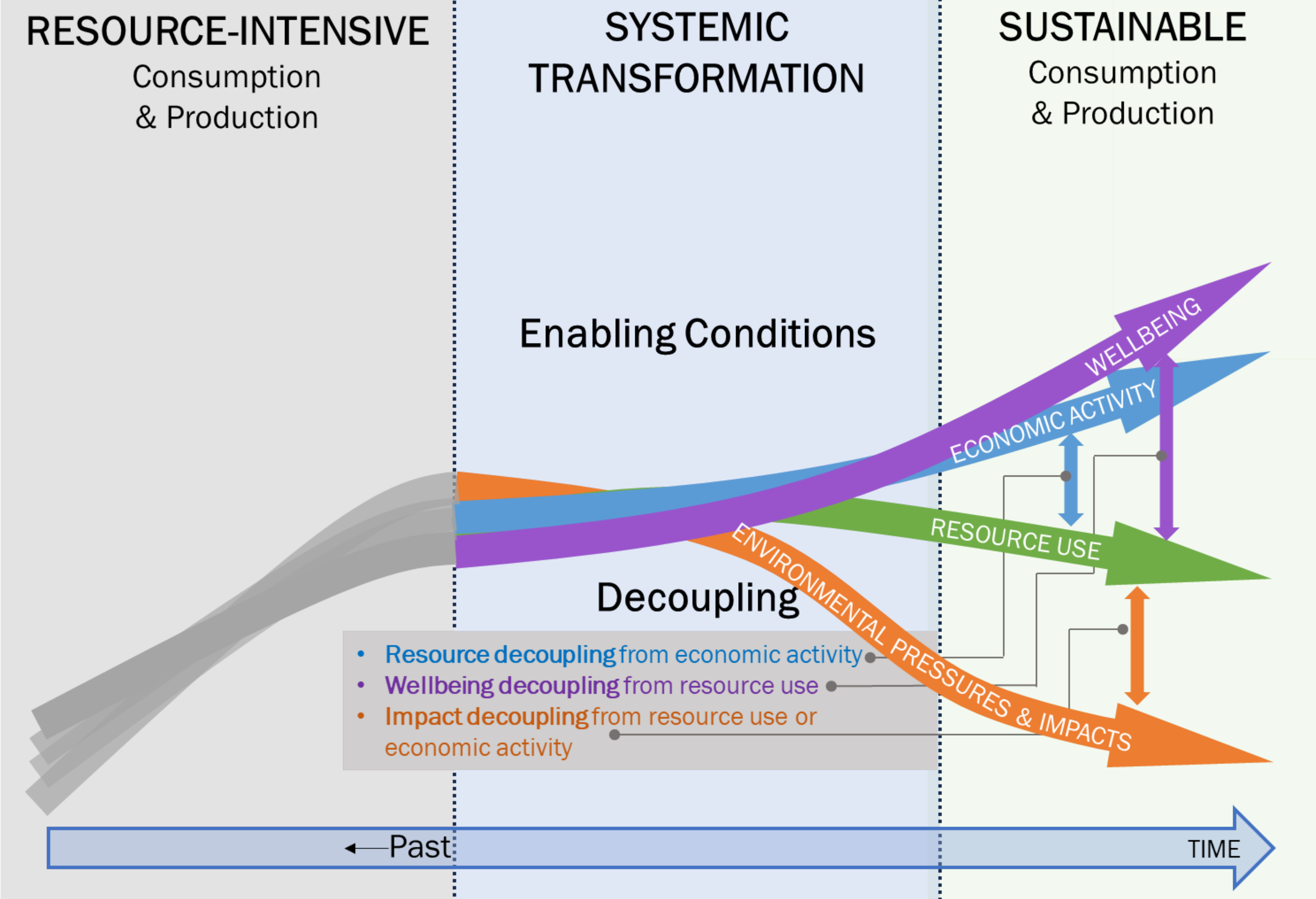
MFI (Materials Flows through Industry): an NREL tool for environmental and material flow analysis of industrial supply chains

EEIO-IDA (Environmentally Extended Input/Output for Industrial Decarbonization Analysis): an IEDO-developed model for analysis of emissions accrual through industry supply chains

TECHTEST (Techno-economic, Energy, and Carbon Heuristic Tool for Early Stage Technologies): an IEDO-developed Excel tool for simplified life cycle assessment (LCA) and technoeconomic analysis (TEA) of low-TRL technologies

LIGHTEnUP (Lifecycle Industry GreenHouse gas, Technology, and Energy through the Use Phase): an LBNL developed tool for forecasting product and sector life-cycle energy and emissions across the US economy

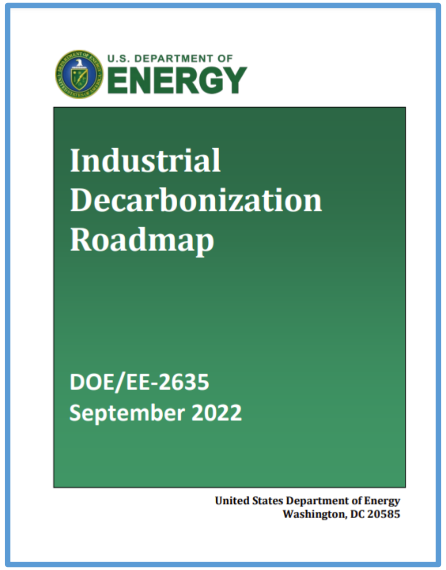
An equitable industrial transformation requires **resource decoupling**.



Adapted from Global Resources Outlook 2024 | UNEP - UN Environment Programme

A Strategy Built Upon Prior DOE Work

- Prioritized near- and mid-term objectives
- Provided limited resolutions for 60% of emissions where cost-effective solutions do not yet exist



- Brought opportunity space into focus
- Highlighted a range of opportunities without charting a course with multiple pathways

New Vision Study: *Pathways for U.S. Industrial Transformations* will…

- Expand solutions for 60+% of emissions reductions where cost-effective technologies don't yet exist
- Provide frameworks for pursuing multiple pathways in parallel
- Identify barriers to pursuing pathways
- Address potential impact on health, workforce, and environment

Scope: Where the *Pathways* Vision Study builds upon the *Roadmap*

	Energy- and Emissions-Intensive Industries	Cross-Sectoral
Pillars	*Roadmap*	*Roadmap + Pathways*
Production Routes, Core Technologies	*Roadmap + Pathways*	*Pathways*

The Path Forward

Building on the foundation of the Industrial Decarbonization 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.

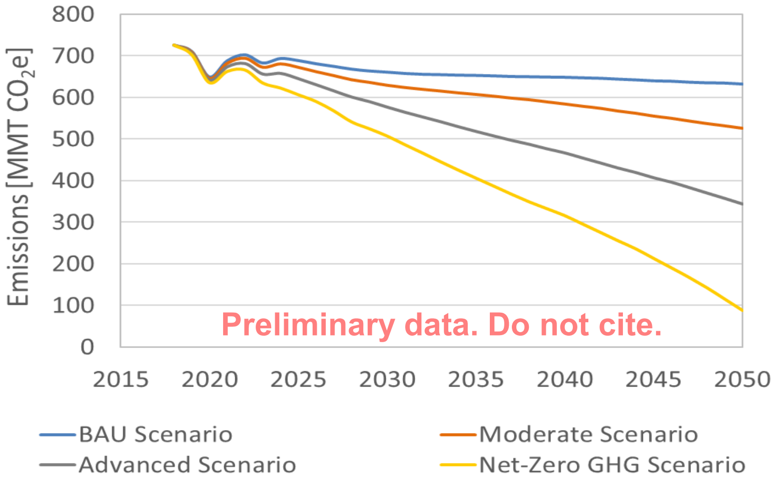
Approach for an Industrial Pathways Vision Study

Elucidate pathways to decarbonize U.S. industry by 2050

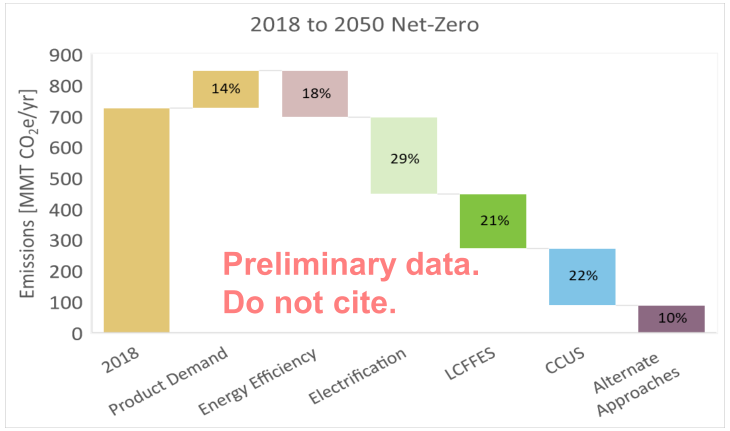
- Expand and extend Industrial Decarb Roadmap approach
- Thorough assessment of barriers
- Decision tree and solutions space frameworks
- Increase resolution of analysis to chart pathways options

Decarbonizing industry is a systems challenge

- From unit operations to facilities to beyond the plant boundaries
- Many pathways require coordination across and outside of industry
- Engage broader cross-section of stakeholders and issues



CO_2e emissions (million MT/year) forecast for six U.S. manufacturing subsectors by scenario, 2018-2050.



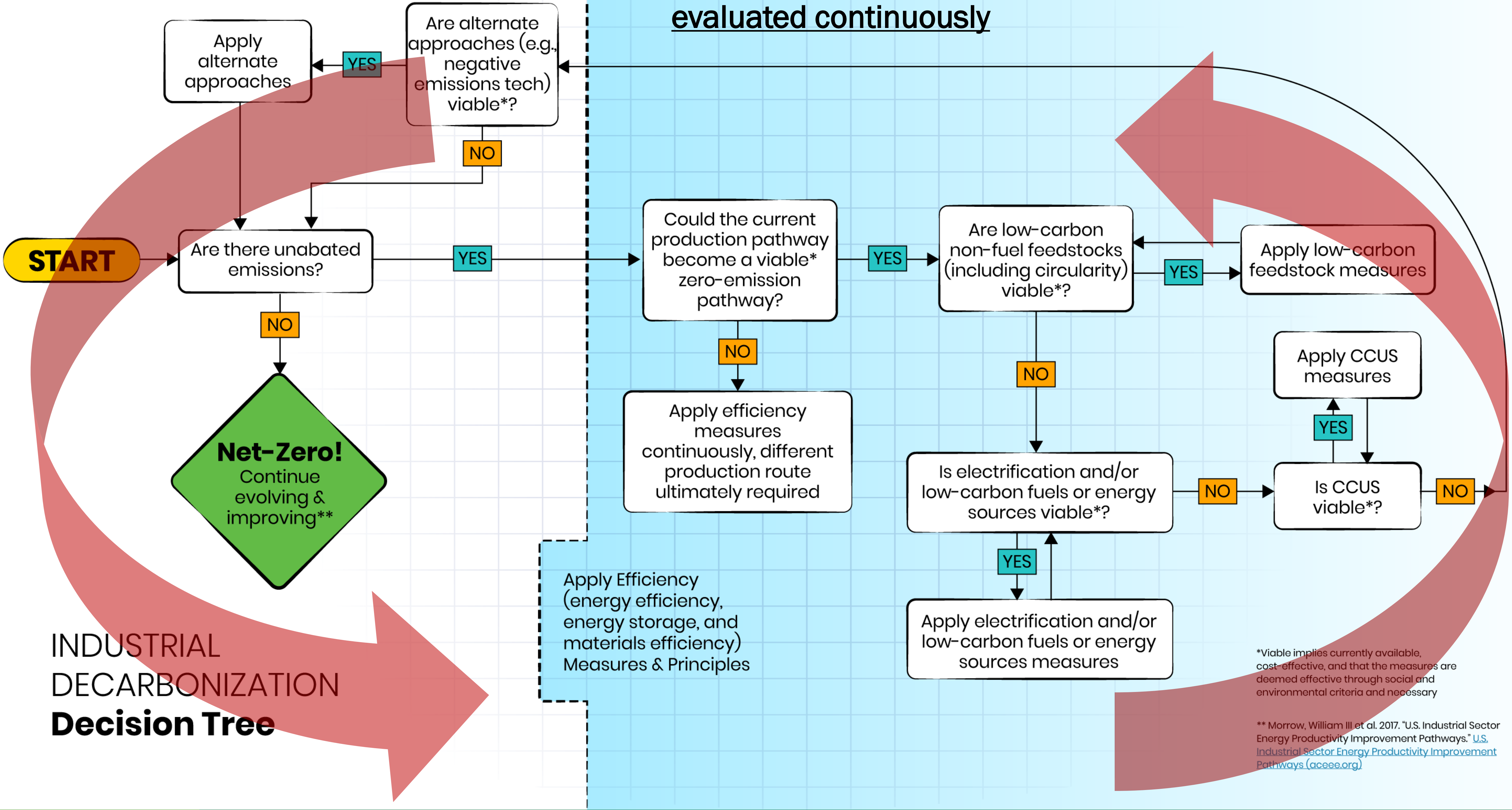
Impact of decarbonization pillars on CO_2e emissions (million MT/year) for six U.S. manufacturing subsectors, 2018-2050 under Net-Zero GHG scenario.

Decision Trees in Context with IEDO Industrial Decarbonization Modeling

Decision trees are frameworks that represent options available to industry as represented in the models. They are intended to be:

- **A starting point** for more targeted use cases depending on factors applicable to the "user" of the decision tree.
- **Adaptive:** While the outputs of our models use assumptions about, for example, anticipated changes and aggregated uptake of technologies over time for a given industrial subsector, decision trees can be adapted.
- **Iterative:** Decision trees evolve over time as technologies evolve, as barriers are overcome, etc.

Pillars of industrial decarbonization must be **pursued and evaluated continuously**



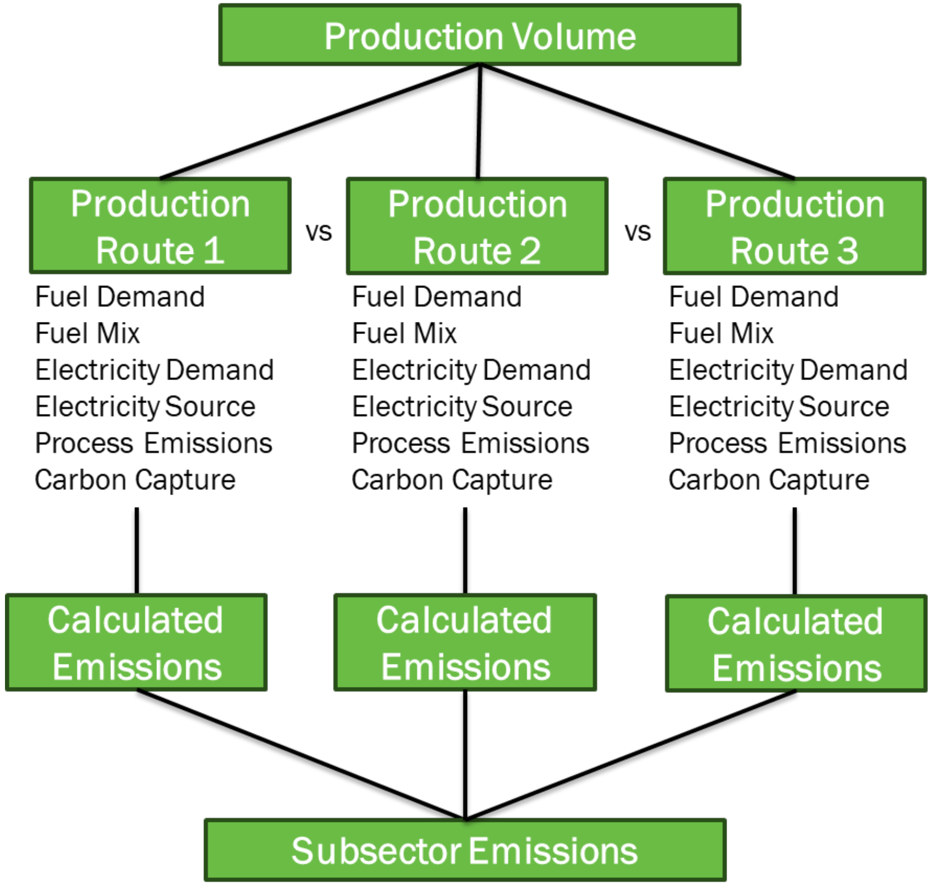
INDUSTRIAL DECARBONIZATION **Decision Tree**

*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)

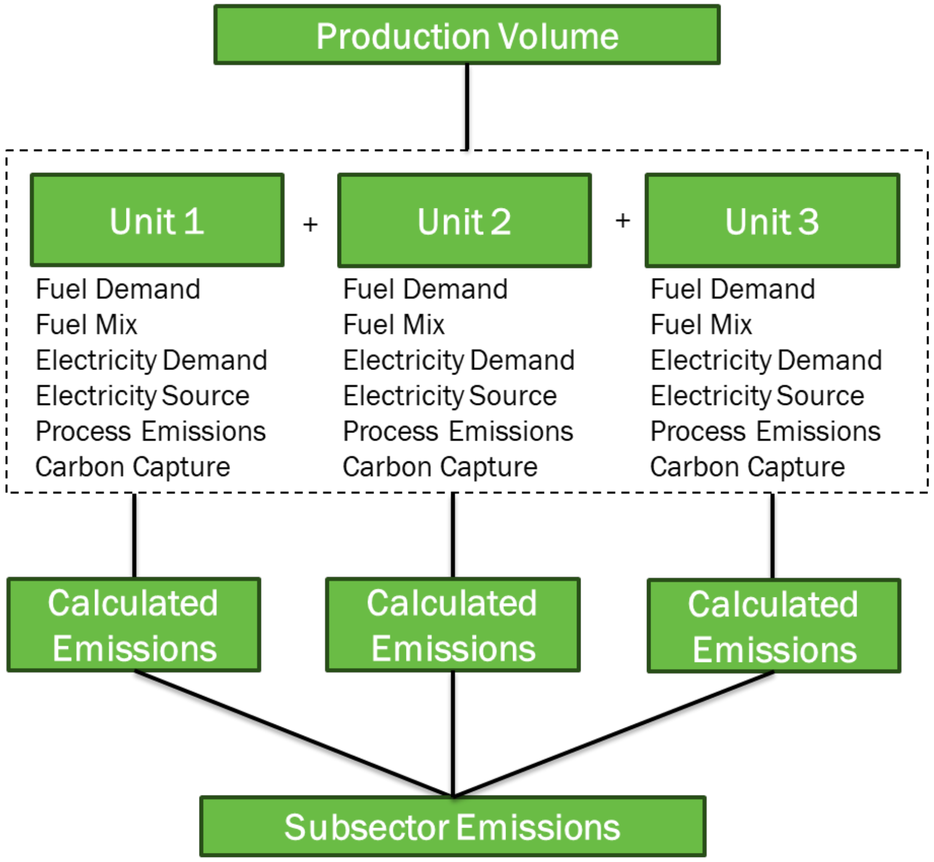
Net-Zero Pathway Modeling Structure

By alternate production route



Chemicals, cement, and iron & steel

By higher resolution of a production route



Petroleum refining, pulp & paper, and food & beverage

Net-Zero Pathway Models

Annual forecast of production volume

2018

Traditional Technologies

2050

Next-Generation Technologies

Modeled Subsectors

- Chemicals
- Cement & Concrete
- Petroleum Refining
- Food & Beverage
- Iron & Steel
- Pulp & Paper

Excel-based models estimate energy- and process-related emissions for select industrial processes based on assumed feedstocks, manufacturing technologies, energy intensities, and energy sources tailored for each subsector

Modeled Decarbonization Scenarios

Customized spreadsheet template for each sector

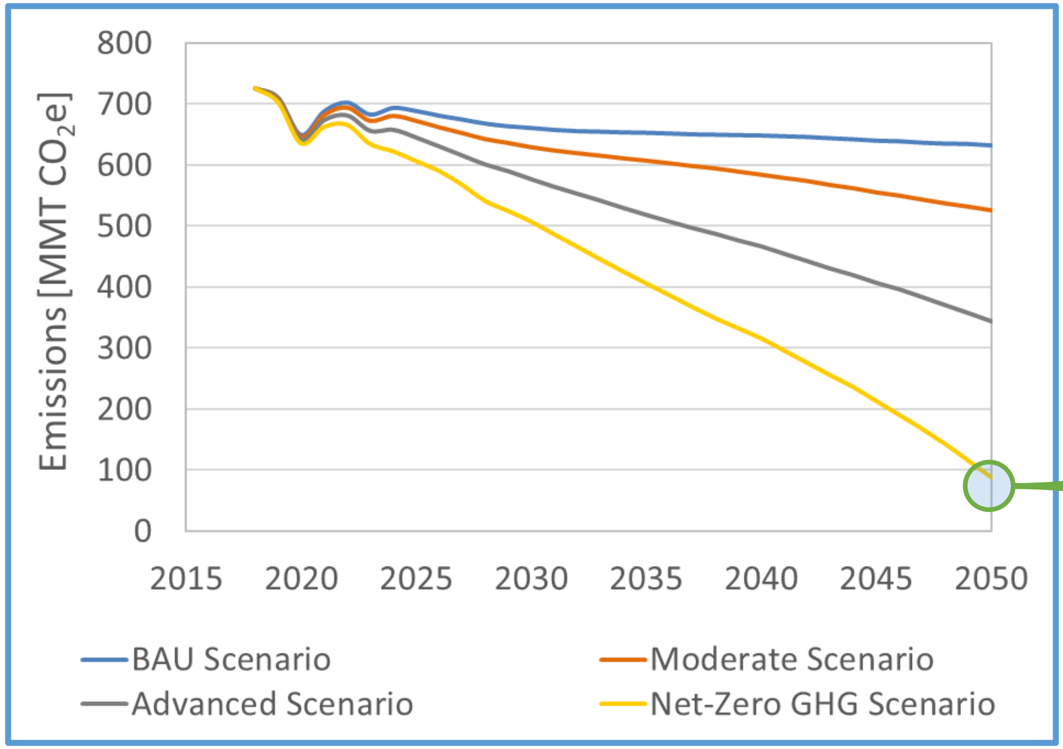
- Chemicals
- Petroleum Refining
- Iron & Steel
- Cement & Concrete
- Food & Beverage
- Pulp & Paper

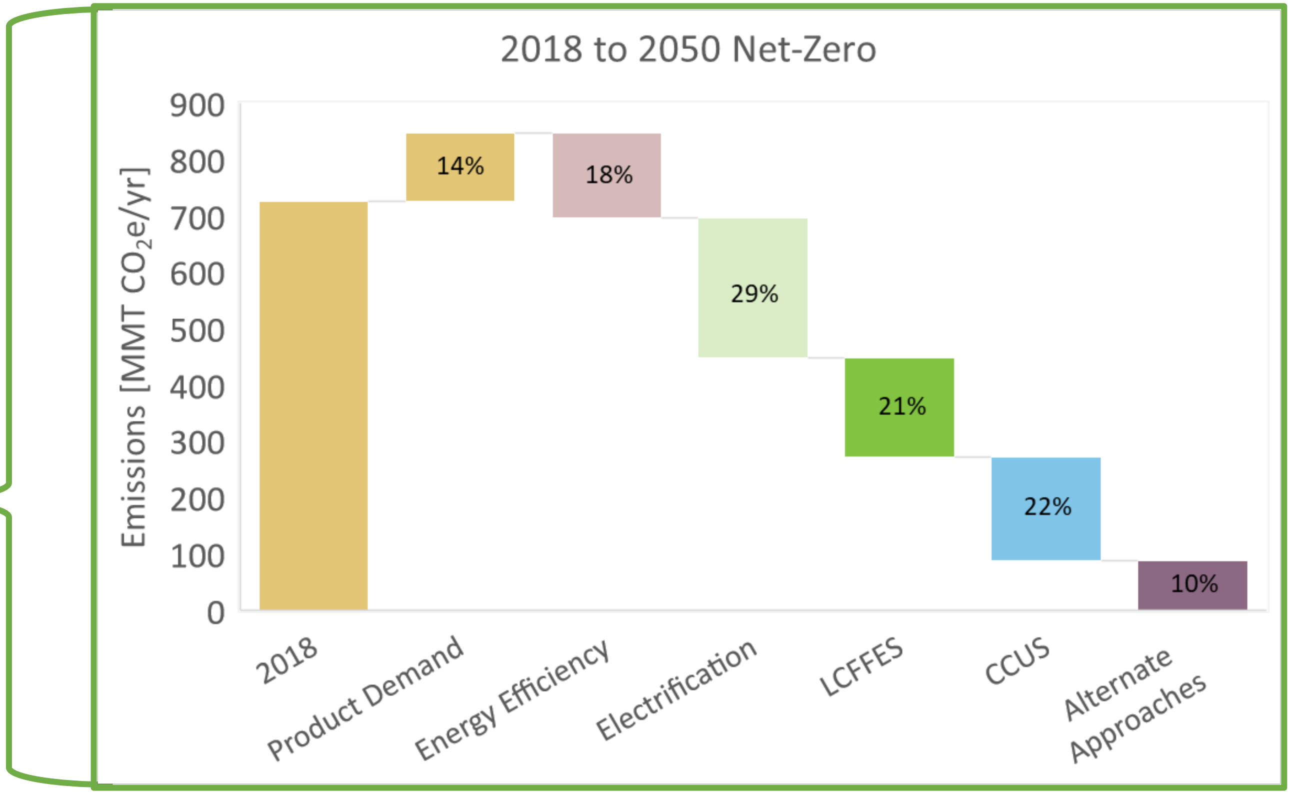
Scenarios

- Business as Usual (“BAU”)
- Moderate Technology and Policy (“Moderate”)
- Advanced Technology and Policy (“Advanced”)
- **Net-Zero GHG Emissions (“Net-Zero”)**

Most aggressive change

Net-Zero Scenario Detail





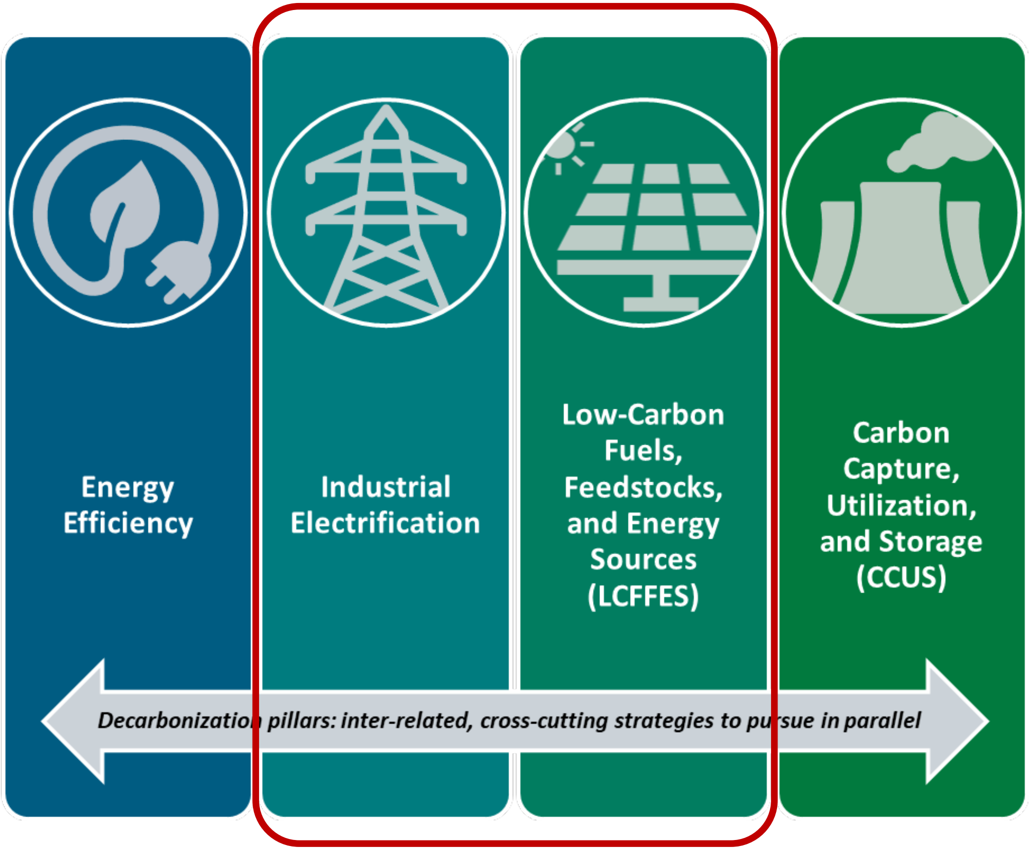
PRELIMINARY DATA. DO NOT CITE.

Example decarbonization scenarios with impact of decarbonization pillars on CO_2e emissions (million metric tons (MMT)/year) for six U.S. manufacturing subsectors*, 2018–2050

Subsector detail available in *Pathways Analysis Summary*

***Subsectors included in Pathways analysis:** Iron & Steel, Petroleum Refining, Cement, select chemicals (ethylene, propylene, butadiene, BTX (benzene, toluene, xylenes), chlor-alkali, chlorine, sodium hydroxide (caustic soda), sodium carbonate (soda ash), ethanol, methanol, and ammonia), pulp & paper, and select food & beverage subsectors (grain and oilseed milling; sugar; fruit and vegetable preserving and specialty food; dairy products; animal slaughtering and processing; and beverages). *This figure may differ to the associated Roadmap figure due to additional modeling considerations included.*

Scenario representation – RM vs. Pathways Vision Study



Tiered approach

Tier 1 - Industrial Decarbonization Pillars

Tier 2 - Sub-category disaggregation / RD&D priority, e.g.:

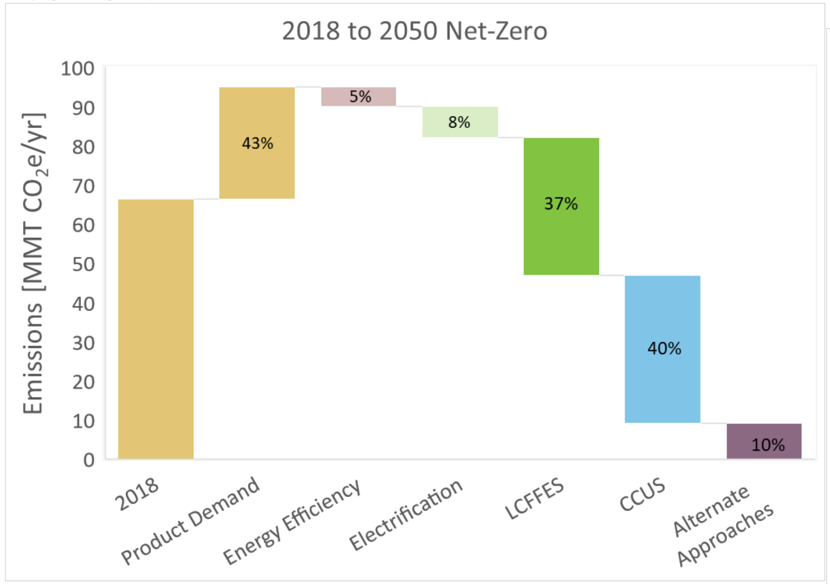
- Carbon utilization vs. storage
- Low-carbon feedstock vs. fuel

Tier 3 - Specific technologies

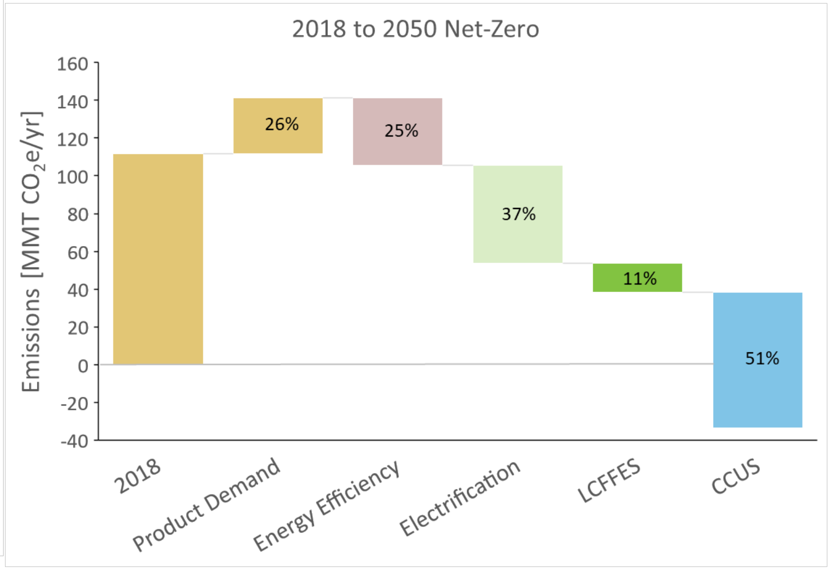
Represented in Roadmap → *Represented in Pathways Vision Study*

Net-Zero Pathway – Preliminary Modeling Results

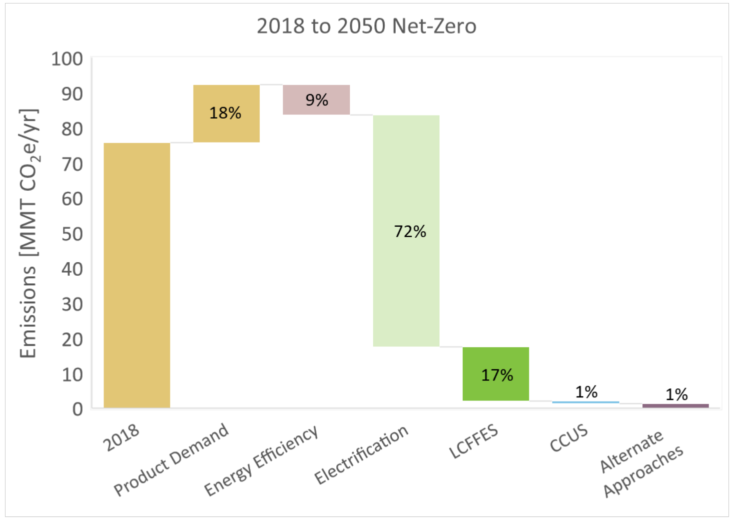
Cement



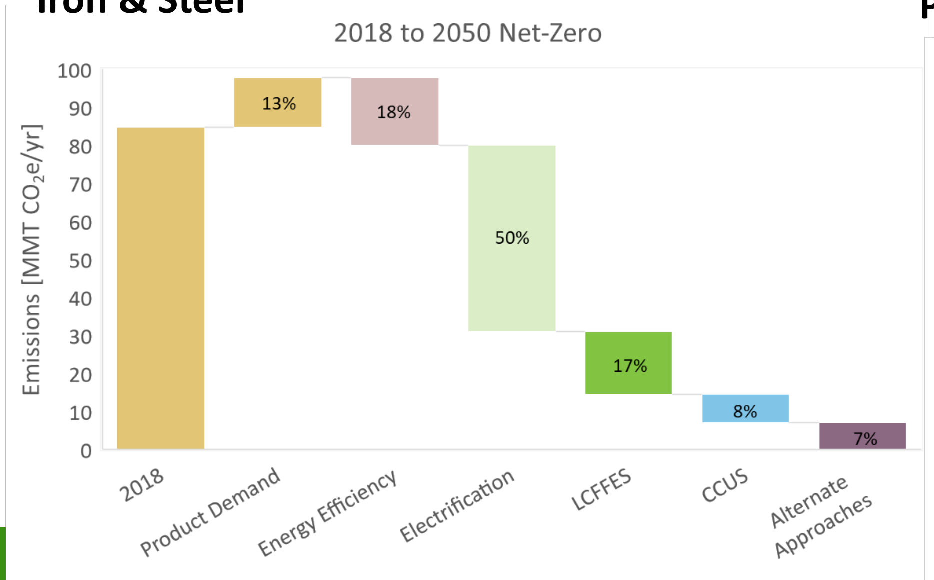
Chemicals



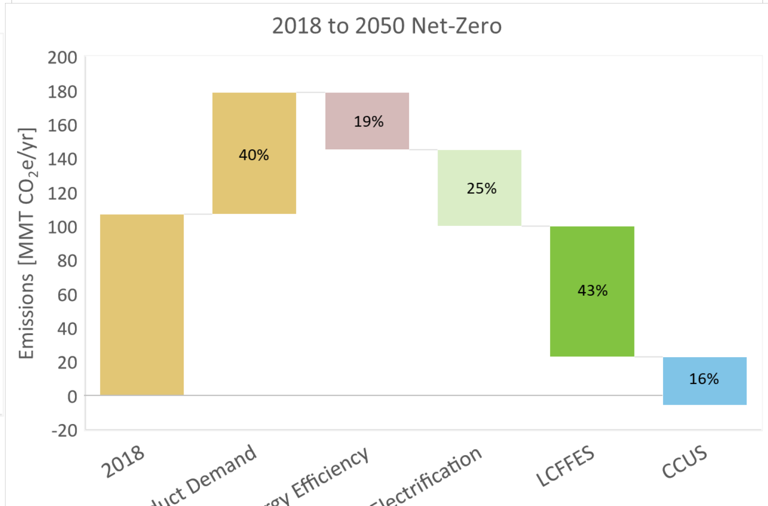
Food & Beverage



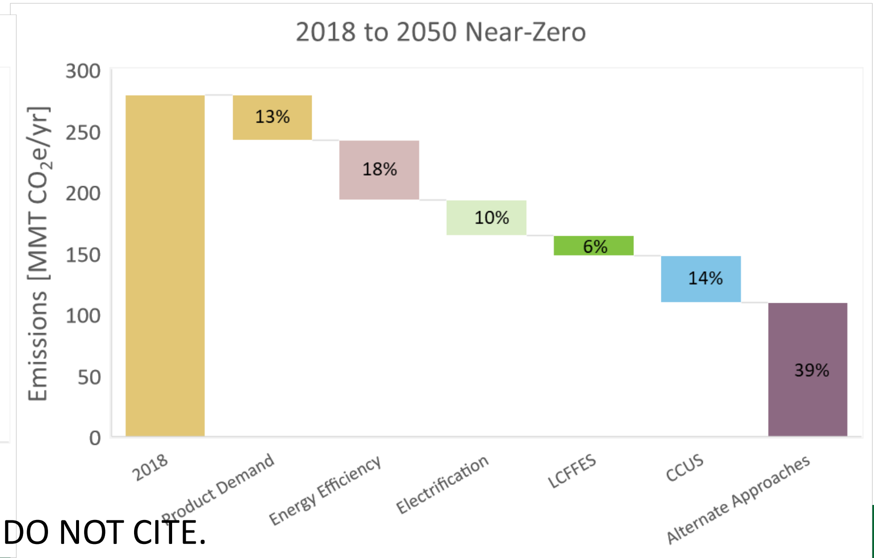
Iron & Steel



Pulp & Paper



Petroleum Refining

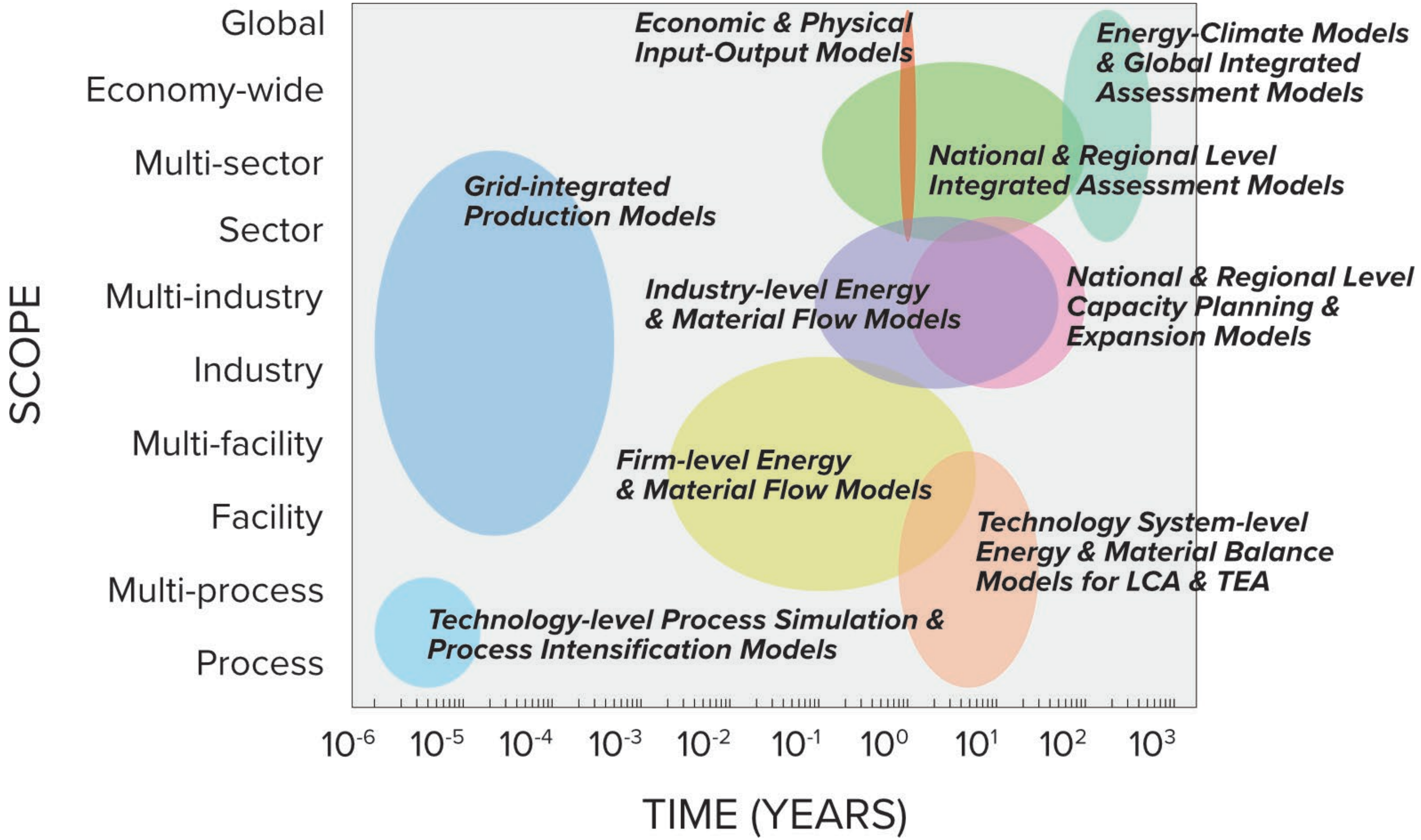


PRELIMINARY DATA. DO NOT CITE.

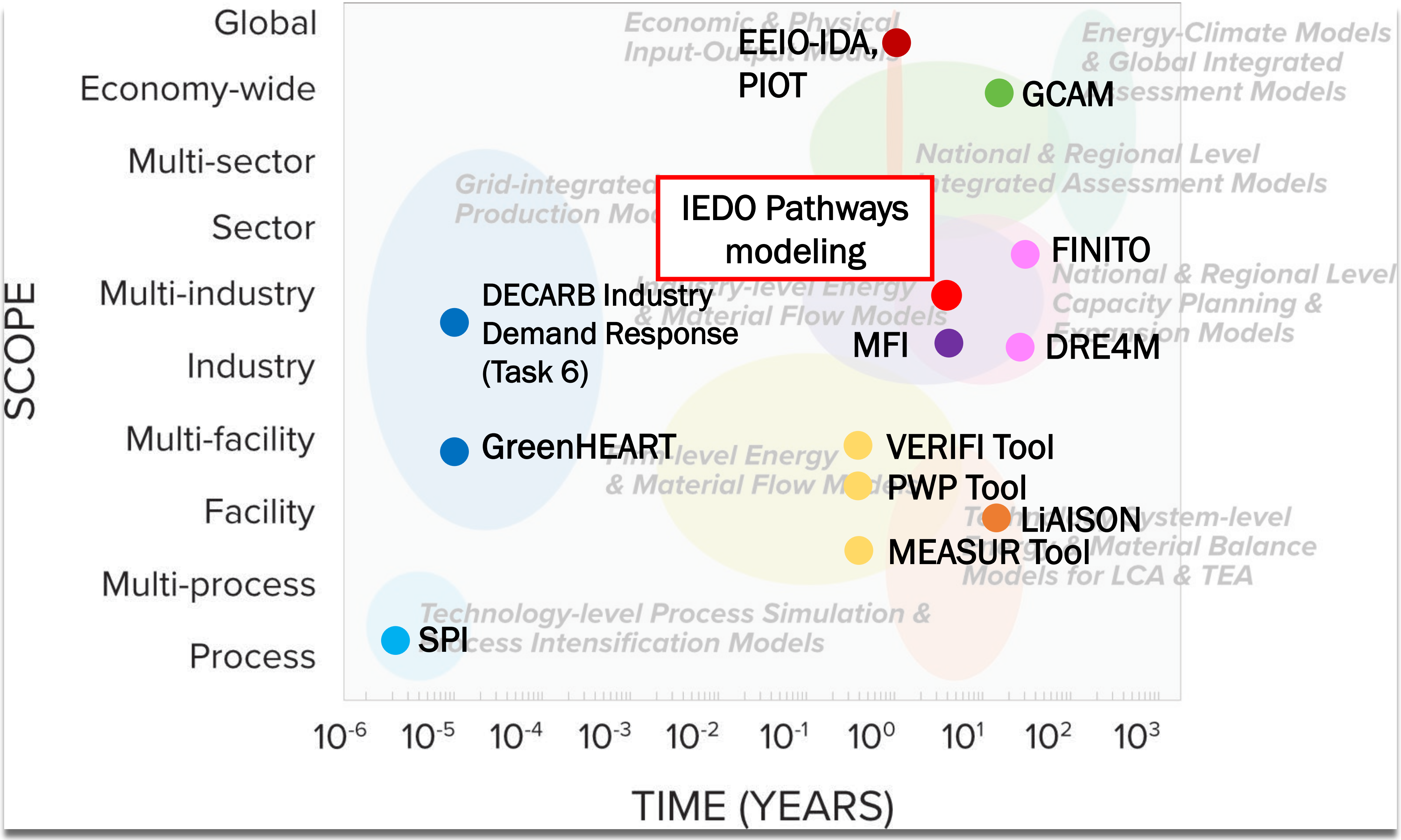
Models Features and Functionalities

Characterizes major incumbent and future technologies	• Energy inputs (both as fuels and feedstocks), products, and unit operation level
Characterizes production capacity and demand for products	• Incorporates (where applicable) considerations demand reduction via substitution and material efficiency
Represents on-site and purchased electricity	• Includes expected decarbonization of the electricity supply sector
Implements consistent set of cross-cutting technology characteristics	• For fuels (e.g., higher heating value, carbon content, biogenic content), derived energy sources (e.g., hydrogen), and carbon capture (e.g., capture rates, energy penalties)
Implements consistent carbon mass balance approach	• Tracks Scope 1 and 2 (and Scope 3 as needed) emissions within and across subsectors, allows for carbon sequestration and utilization and biogenic content of fuels and feedstocks
Provides annual time series representation	• Track major technology variables and parameters such that production, energy use, and emissions on annual basis
Allows systematic scenario development	• Technology characteristics, demand projections, stock turnover rates, and other key model parameters can be varied

Landscape of Energy Systems Models in Industry Context



Select IEDO and IEDO-Adjacent Models on Landscape



- [DECARB](#) (Decarbonizing Energy through Collaborative Analysis of Routes and Benefits)
- [DRE4M](#) (Decarbonization Roadmapping and Energy, Environmental, Economic, and Equity Analysis Model)
- [EEIO-IDA](#) (Environmentally-Extended Input-Output for Industrial Decarb Analysis)
- FINITO (Fuels and Industry Integrated Optimization Model)
- GCAM (Global Change Assessment Model)
- [LiAISON](#) (Life cycle Analysis Integration Into open-SOurce Numerical models)
- [MEASUR](#) (Manufacturing Energy Assessment Software for Utility Reduction)
- [MFI](#) (Materials Flows through Industry)
- PIOT (Physical Input-Output Tool)
- [PWP](#) (Plant Water Profiler)
- SPI (Systematic Process Intensification)
- [VERIFI](#) (Visualizing Energy Reporting Information and Financial Implications)

Framework for Industrial Decarbonization Pathways

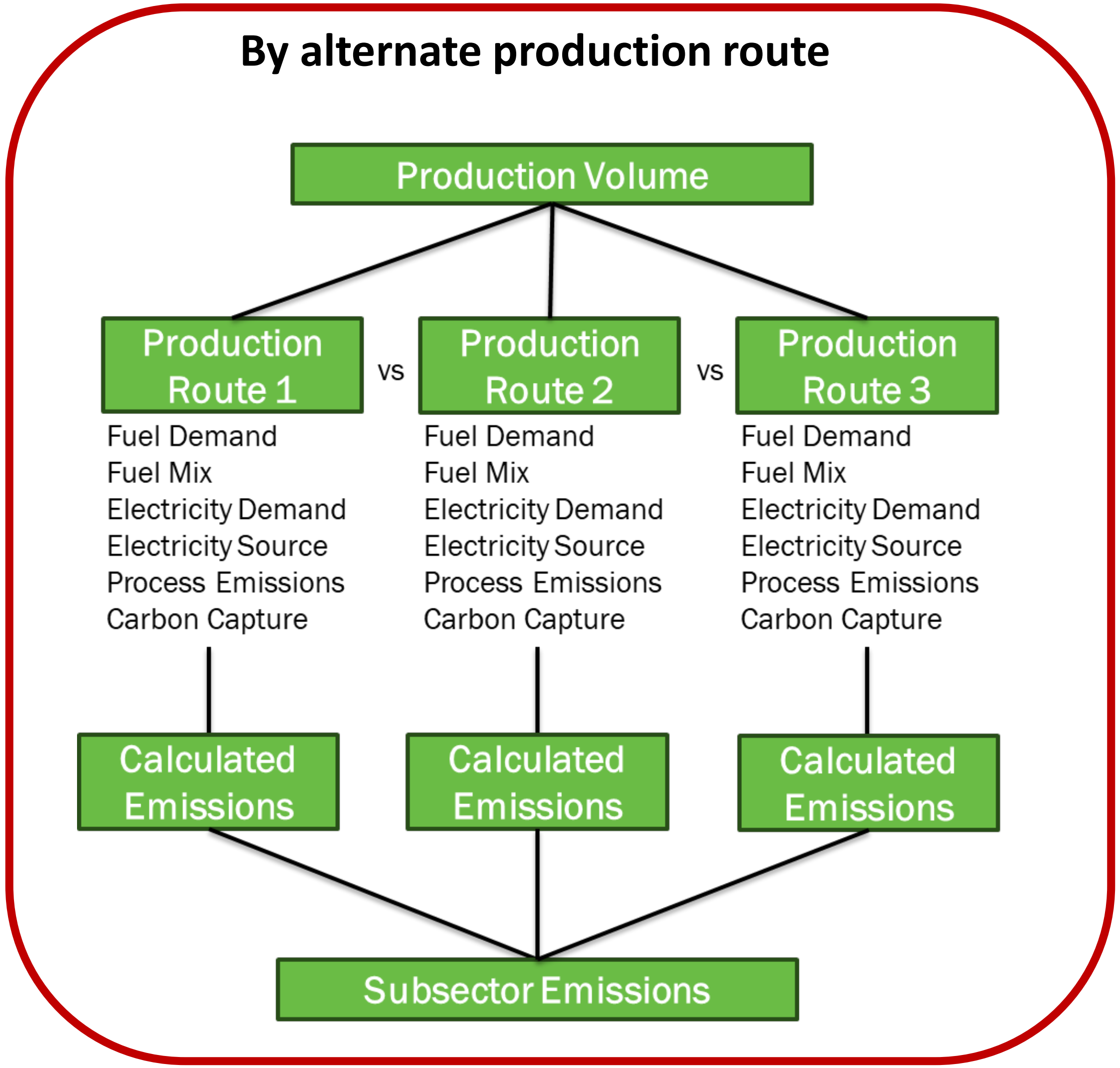
Net-Zero Emissions Pathway: A set of specific actions needed to achieve progress in and across the decarbonization pillars, while remaining informed and supplemented by RD&D to advance viable solutions that will need to be adopted at scale in the marketplace.

- 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

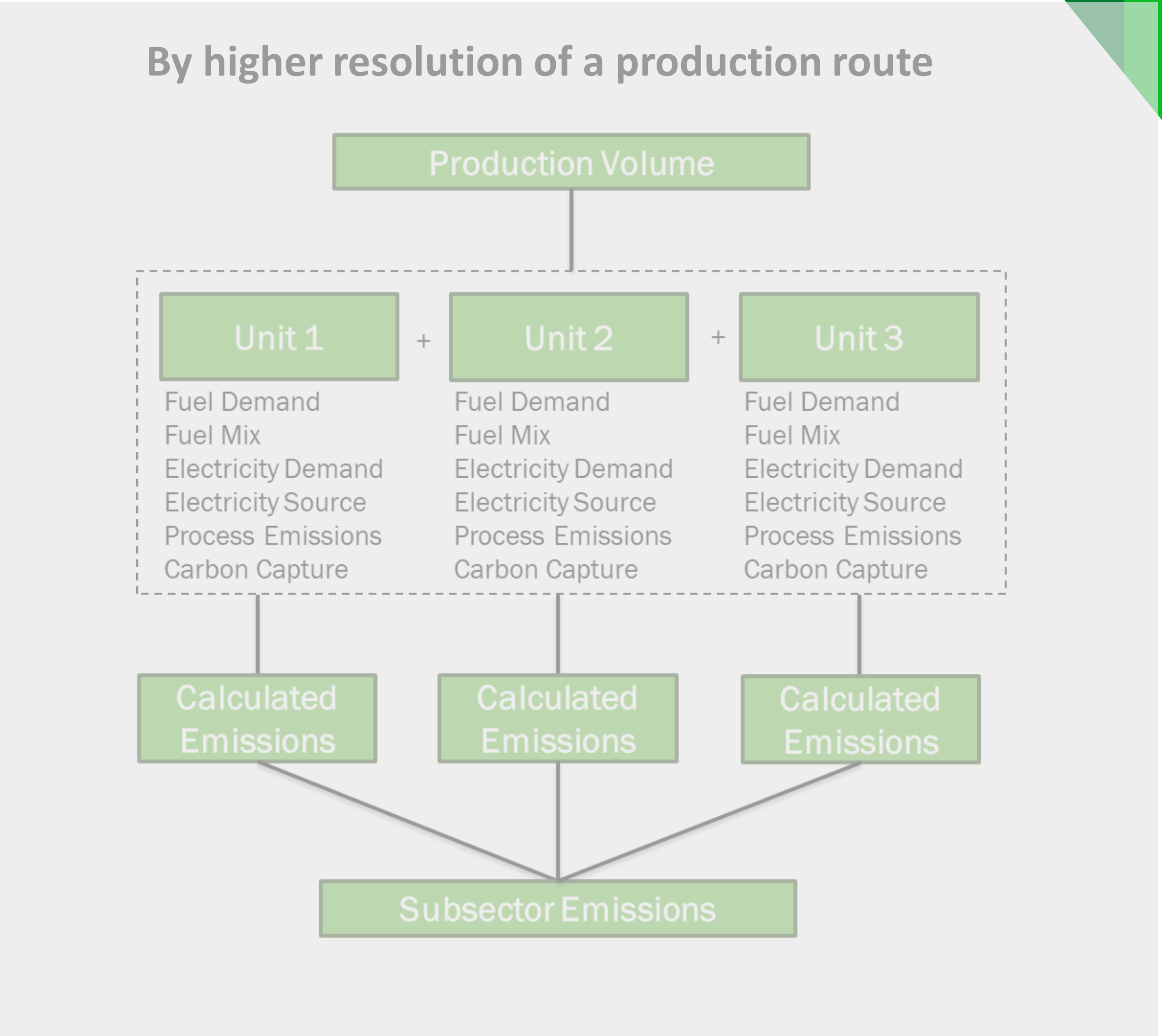
Defined sensitivities included in modeling → Help to identify high/low potential Pathways

1. Hydrogen price/availability/emission factors 2. Electricity price/availability/emission factors 3. CCS capture price/availability/efficiency 4. Efficiency improvements, by TRL	Global – harmonized definition across all subsectors
5. Market share of low-TRL technologies 6. Alternative energy sources 7. Changes in modeled demand 8. Feedstock availability & quality	Subsector-specific definitions

Net-Zero Pathway Modeling Structure

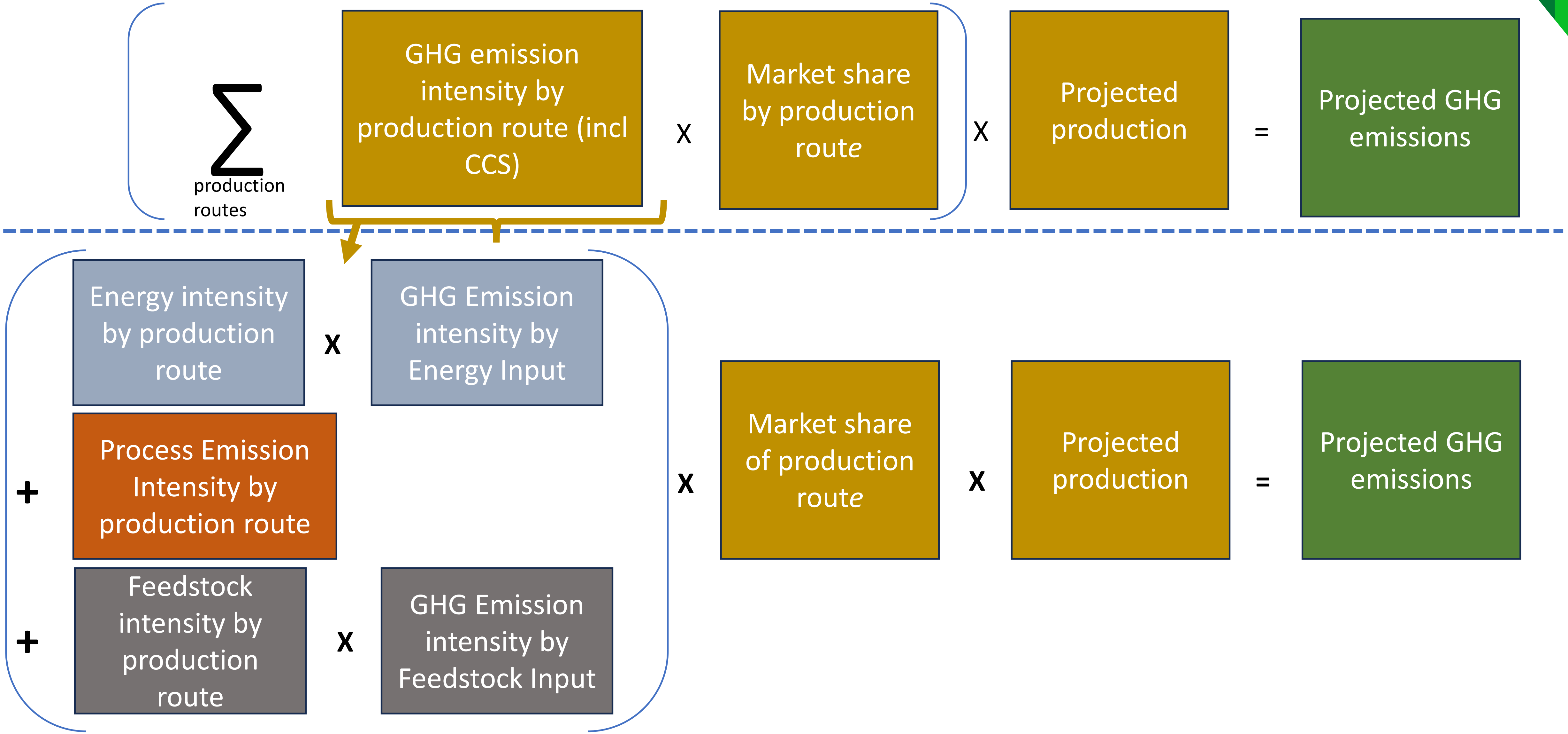


Chemicals, cement, and iron & steel



Petroleum refining, pulp & paper, and food & beverage

Industrial Decarbonization Modeling Overview – (Overly) Simplified Calculations for Iron & Steel



Iron & Steel Production Routes

8 production pathways, with variable scrap input allowed for to achieve mass balance requirements of a scenario

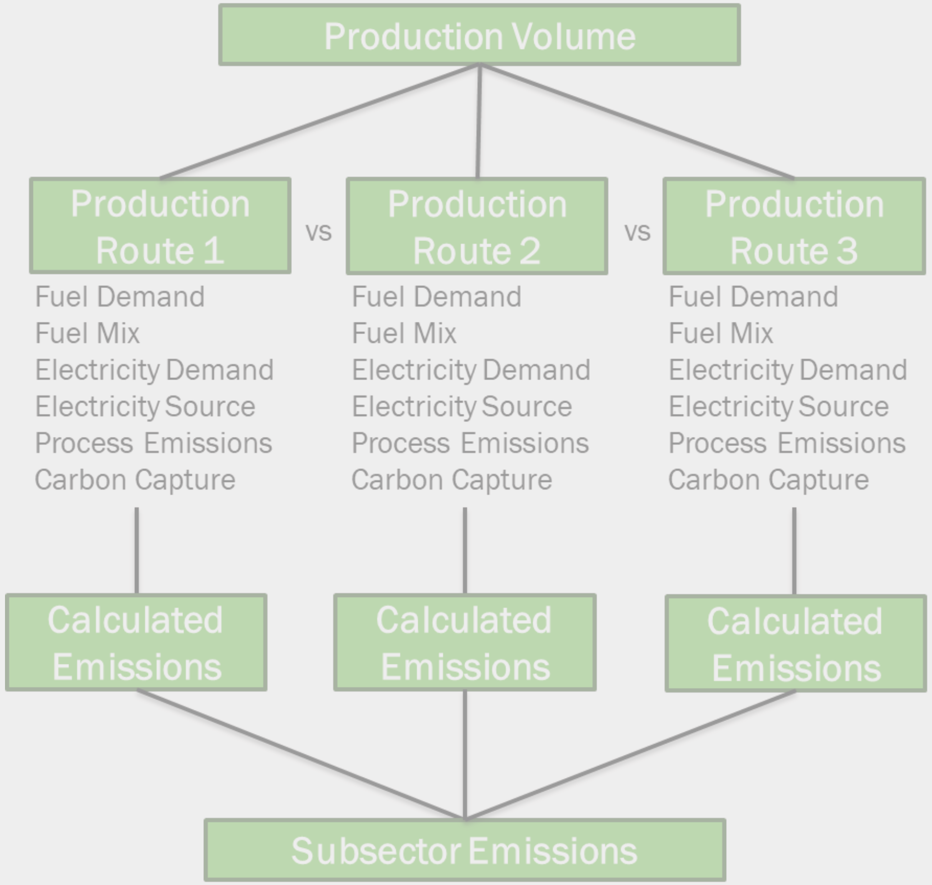
1. Blast furnace (BF)-basic oxygen furnace (BOF)
2. BF-BOF with carbon capture and storage (CCS)
3. Natural gas (NG)-direct reduced iron (DRI)-electric arc furnace (EAF)
4. NG-DRI-EAF with CCS
5. Hydrogen (H_2)-DRI-EAF
6. Molten oxide electrolysis (MOE)-EAF
7. Aqueous electrolysis (AqE)-EAF
8. Scrap-EAF

Iron & Steel Potential Preliminary Takeaways (Pathways)

1. Scrap inputs into the subsector are the biggest driver for emission trajectories
   - Reducing scrap input by ~50% can ~double the total emissions
2. Electrification and hydrogen are the primary pillars beyond scrap
3. Imports play a large role in offsetting primary iron production
   - Offsetting imports with domestic production - imports represent only ~25% of domestic consumption, but offsetting them will cause ~ doubling of primary iron production with scrap held constant
4. Based on early stakeholder feedback, electrolysis-based production methods are not expected to account for more than ~5-10% of crude steel production in 2050

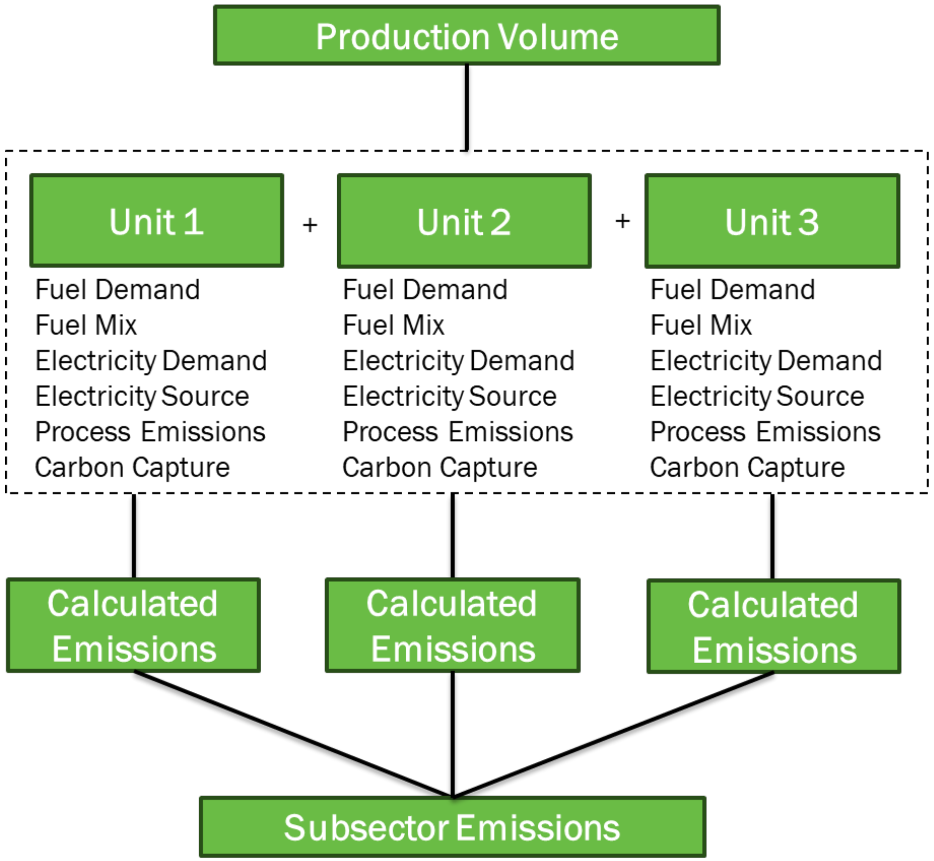
Net-Zero Pathway Modeling Structure

By alternate production route



Chemicals, cement, and iron & steel

By higher resolution of a production route



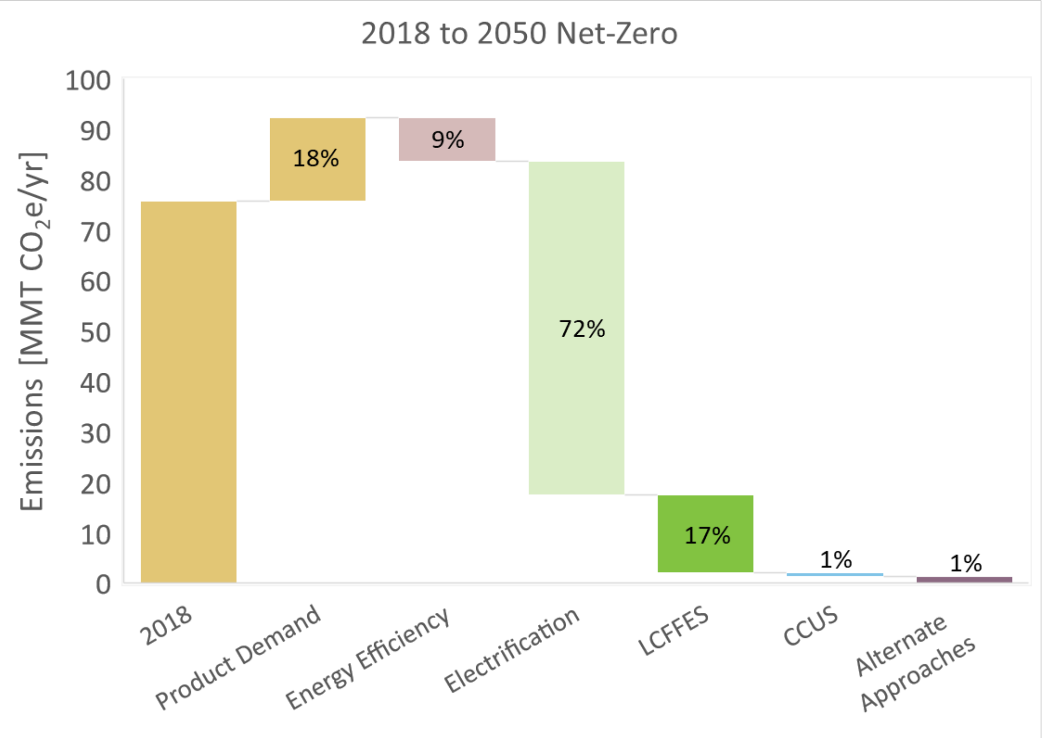
Petroleum refining, pulp & paper, and food & beverage

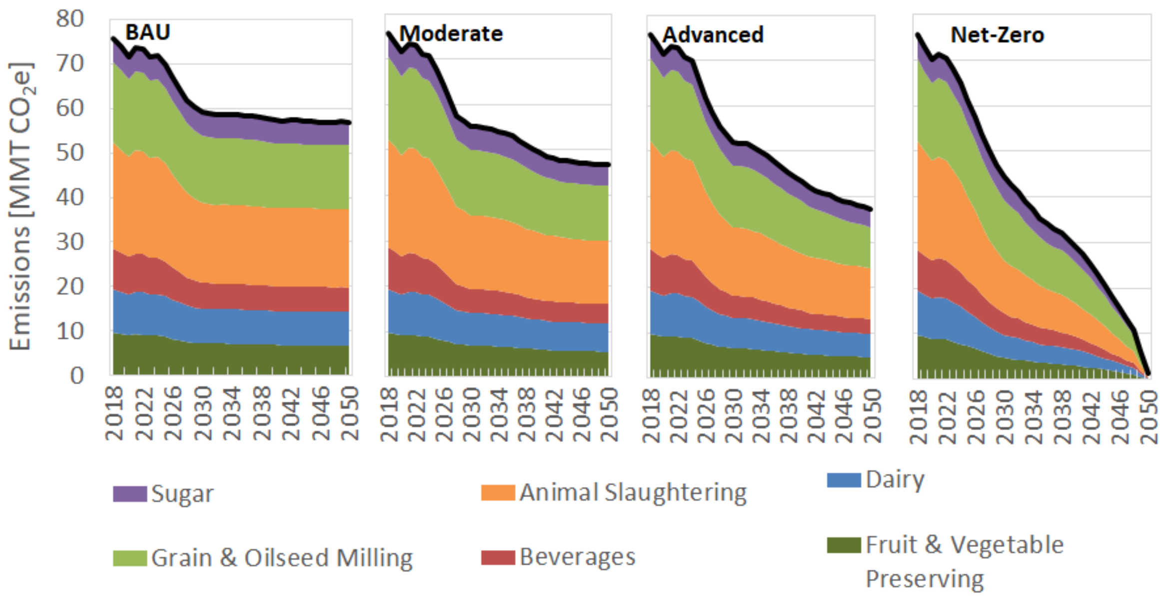
Food & Beverage

- Preliminary results from *Pathways Analysis Summary*

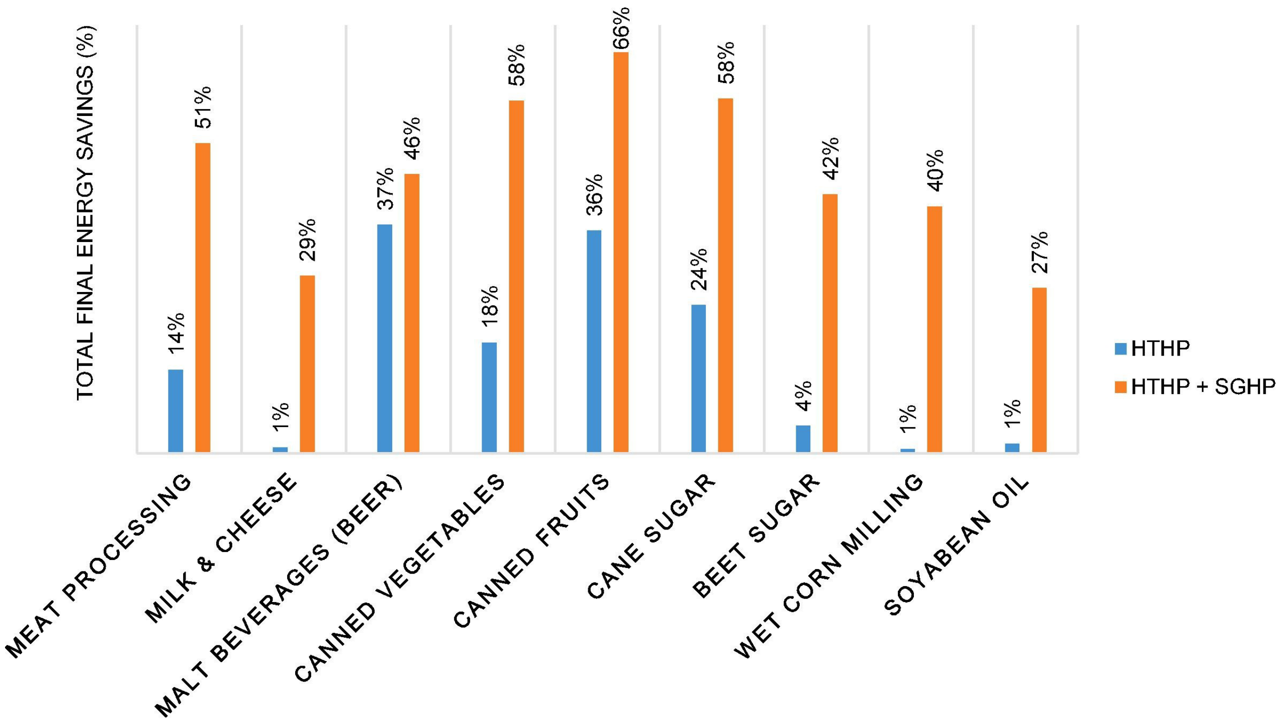
Model includes six subsectors accounting for ~79% of food & bev emissions:

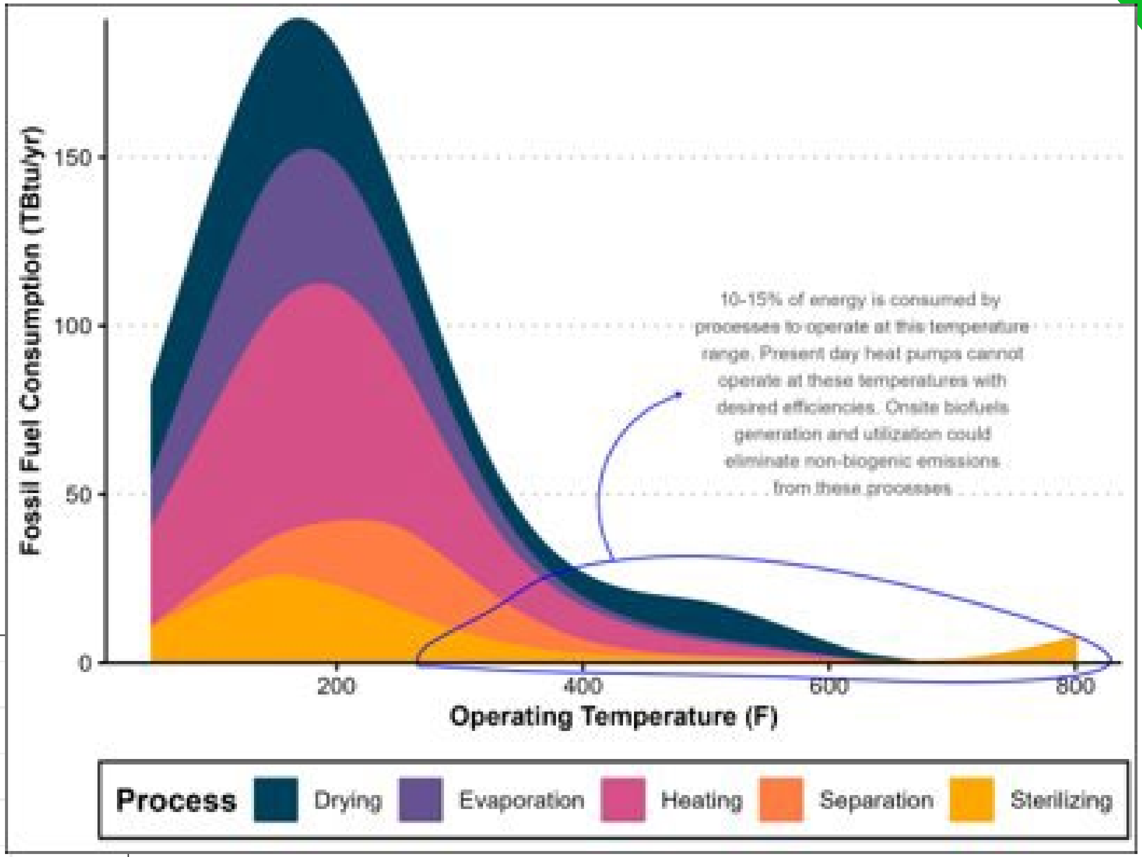
- grain and oilseed milling
- sugar manufacturing
- fruit and vegetable preserving and specialty food manufacturing
- dairy product manufacturing
- animal slaughtering and processing
- beverage manufacturing

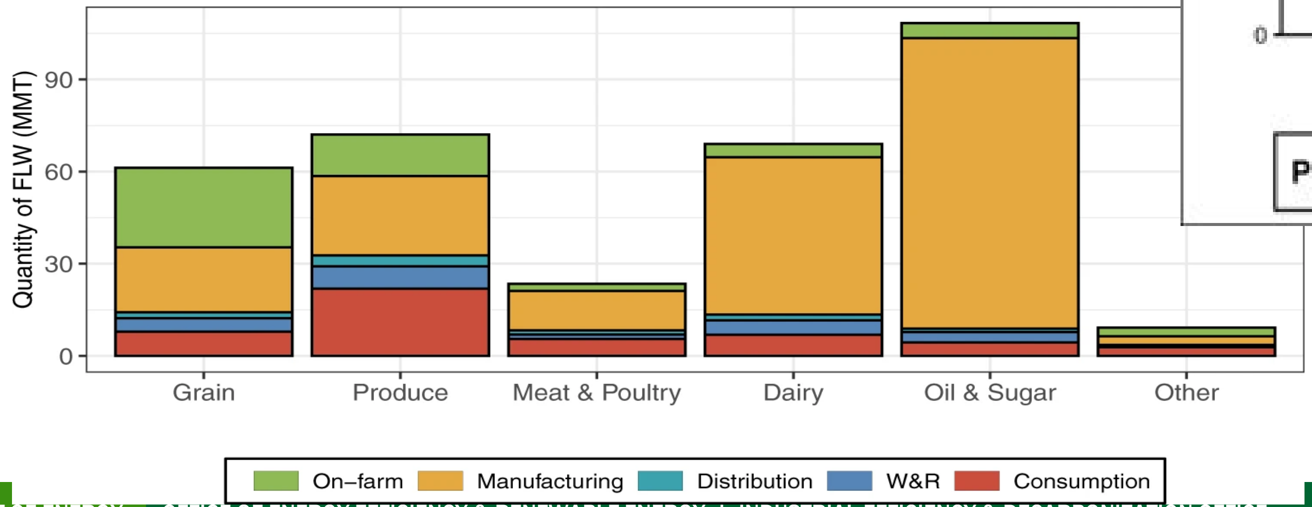




Technology Assessments inform Decarbonization Pathways







Modeled Technologies: Food & Beverage

Technology	Process
Energy Efficiency	
Boiler energy efficiency measures	Facility HVAC
Air Compressors energy efficiency measures	Machine Drive
Chillers energy efficiency measures (Motors/VFD)	Process Cooling and Refrigeration
Dryers/ovens energy efficiency measures	Low/High temp Convective hot air dryers
Fans and Blowers energy efficiency measures	Machine Drive
Process Integration	Low/High temp Convective hot air dryers Low/High temp Direct/Indirect hot water Process Cooling and Refrigeration
Pumps energy efficiency measures	Machine Drive
LCFFES	
Low-carbon fuels switching	Processes with remaining fuel demand
CCUS	
Post-combustion carbon capture and storage (amine absorption)	Remaining combustion emissions (grain and oilseed milling, beverages only)

Subsectors modeled:

- Grain and oilseed milling
- Sugar
- Fruit and vegetable preserving and specialty food
- Dairy products
- Animal slaughtering and processing
- Beverages

Account for 78% of energy and 79% of emissions total for food & bev subsector

Technology	Process
Electrification	
Electric Boiler	Low/High temp Direct/Indirect hot water/Steam
Hot water heat pump	Facility HVAC Low/High temp Direct/Indirect hot water
Membrane Pre-concentrators	Low/High temp convective hot air dryers
Steam generating heat pump	Low/High temp convective hot air dryers Low/High temp Direct/Indirect steam
Advanced electroheating technologies	Low/High temp Convective hot air dryers

Food & beverage sector-specific sensitivities

1. Lower heat pump adoption rates (maybe more realistic for U.S.)
2. Higher LCFFES (bio-based fuels) adoption/ integration
3. Waste heat integration impact for heat pumps using existing waste heat sources, leading to higher coefficients of performance (COPs)/system complexity
4. Higher efficiency, specifically via lowering steam production and increasing hot water use based on temperature demands
5. Reduced downstream food loss impact to food manufacturing output (modeled demand)
6. Very high electrification/expanded electro-technologies (beyond heat pumps)

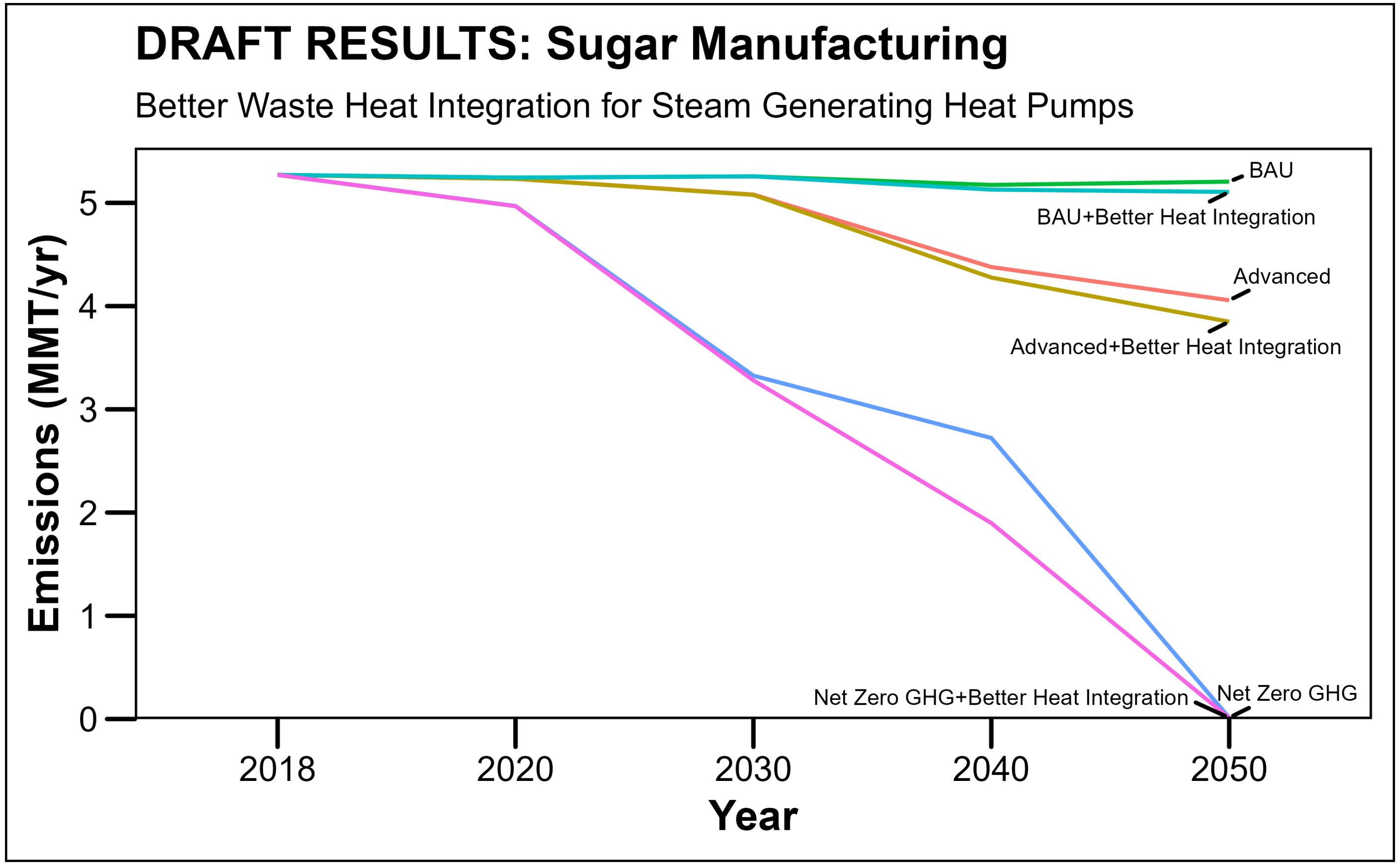
Food & beverage sensitivities/pathways: Example output

- Higher coefficient of performance (COP) for Steam Generating Heat Pumps in Sugar Manufacturing

Heat pump coefficient of performance (COP) values before and after heat integration:

Thermal Processes	Existing COPs	Waste Heat Integration COPs
Low temp indirect steam	2.0	3.8
High temp indirect steam	2.0	3.2
Low temp drying	2.0	3.2

PRELIMINARY DATA. DO NOT CITE.



PRELIMINARY DATA. DO NOT CITE.

Modeling Challenges include …

- Cost projections
- Primary data
- Assumptions regarding adoption of new technologies
- Incorporating energy, equity, and environmental justice (EEEJ) and other externalities into our analysis framework
  - Both positive and negative implications of decarb pathways

Discussion

Adjourn

Thank you!

Industrial Decarbonization Modeling Overview – Model Layout for Iron & Steel

Process/Feedstock
Baseline description of processes and some time series defined for:
- Baseline energy (or GHG for feedstocks) intensity (fixed with time)
- Efficiency improvements p.a. by sensitivity (3 different sensitivities) for processes (and maybe feedstocks)
- Baseline TRL level defined for processes (fixed with time)
- Process emission intensity (fixed with time)
- Baseline excess energy intensity for CCS processes (fixed with time)
- CO2 captured intensity for CCS processes (defined as a capture rate, between 90-95%)
- Scope 3 (0 or 1) (fixed with time)

Production Routes
Processes and feedstocks required per production route, independent of sensitivity, CCS processes are separate production routes
- Feedstock intensity, i.e., yields (kg feedstock/kg crude steel) (fixed with time)

CO2 intensities
Time series for emission factors for energy inputs (maybe feedstocks as well here)
- Defined by sensitivity
- Hydrogen, grid, all other fuels are here

Energy mix of processes
Time series defined for each sensitivity:
- Electricity and fuel inputs to a process

→ GHG emission intensity by production route

X

Adoptions (Market share of Production Routes)
Market share for defined production routes
- S-curve adoptions for defined sensitivities
- Split between production routes with and without scrap based upon inputs of user defined scrap % by year for production route

X

Production Projections (Demand)
Time series defined for each sensitivity:
- Domestic production
  - With current imports fixed
  - Without imports
  - With imports increasing (from Aus, Brazil?)
- Scrap availability, +/-

=

Projected GHG emissions