

Decarbonizing the U.S. Food and Beverage Sector

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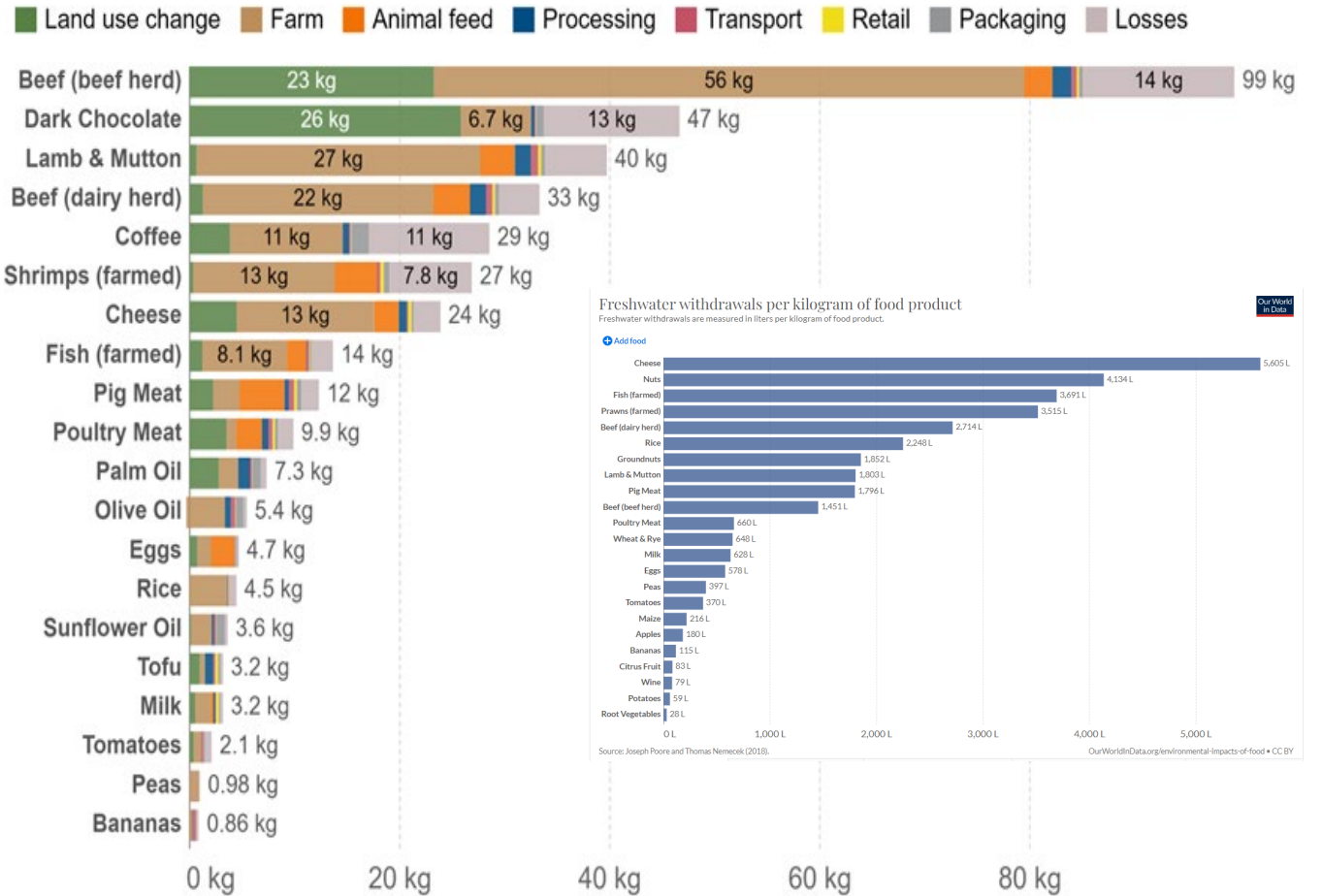
The Global Food System



> 38,000 farms, > 40 products, 119 countries

Food: greenhouse gas emissions across the supply chain

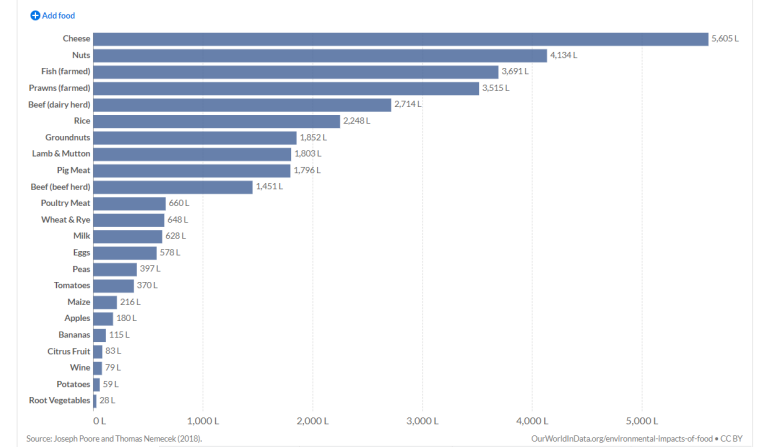
Greenhouse gas emissions are measured in carbon dioxide-equivalents (CO₂e) per kilogram of food.



Source: Joseph Poore and Thomas Nemecek (2018).

Freshwater withdrawals per kilogram of food product

Freshwater withdrawals are measured in liters per kilogram of food product.



Source: Joseph Poore and Thomas Nemecek (2018).

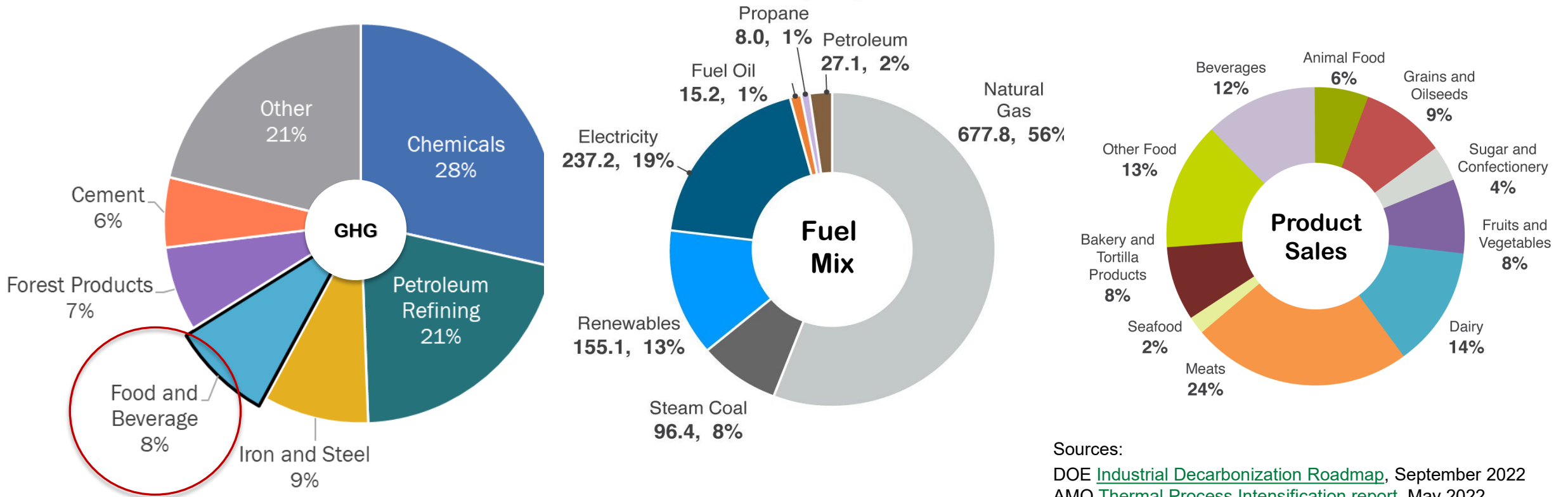
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U.S. Food and Beverage Sector Overview

Food and Beverage Sector is a critical component of the U.S. economy:

- Over 50,000 establishments involved in food and beverage manufacturing [U.S. Bureau of Labor Statistics, 2022]
- Produced and shipped nearly \$950 billion of products and employed approximately 1.7 million workers [USDA 2021]
- Directly consumed ~ 2 quads of energy and accounted for ~ 96 MMT of GHG emissions [MECF 2018]



Sources:

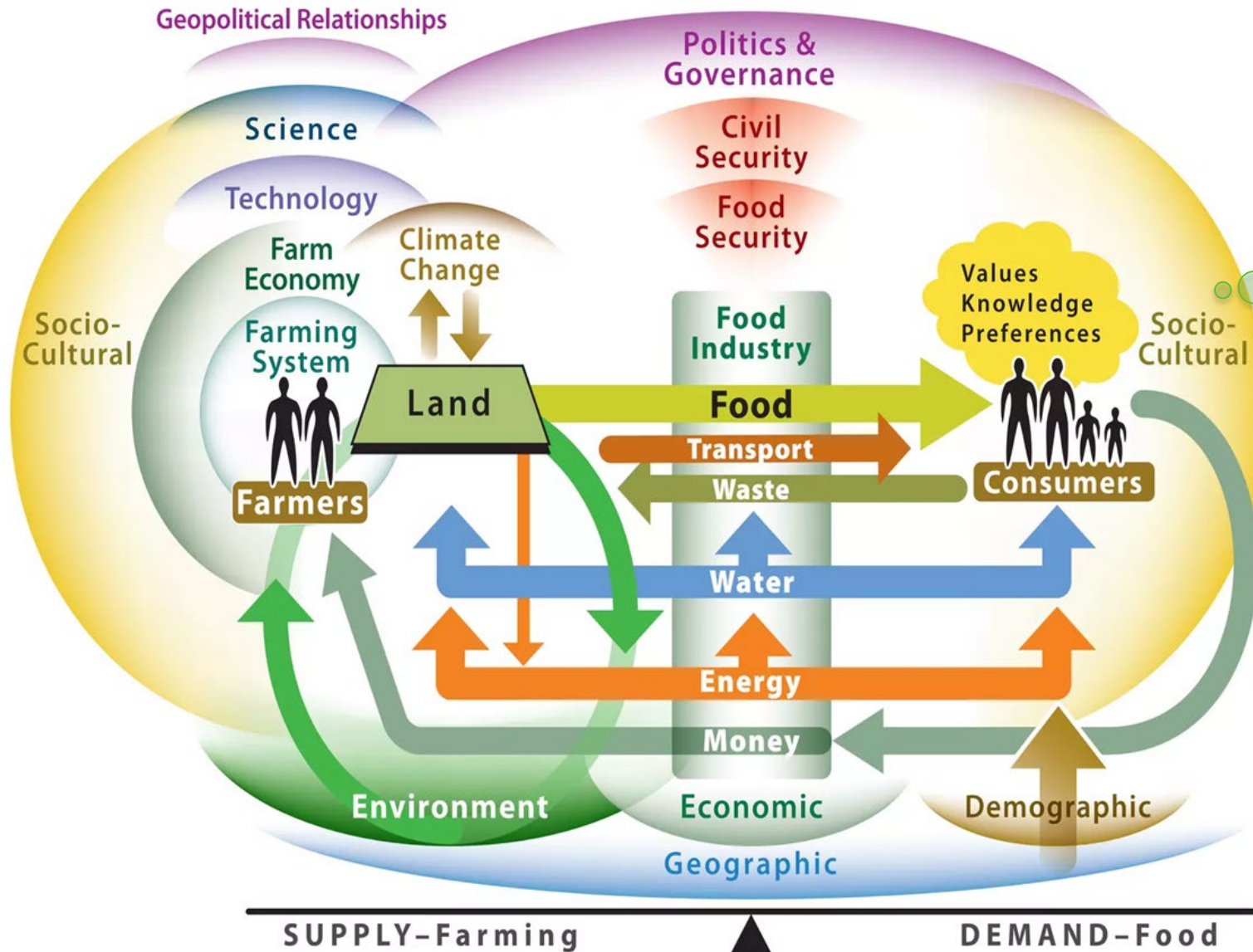
DOE [Industrial Decarbonization Roadmap](#), September 2022

AMO [Thermal Process Intensification report](#), May 2022

USCB [Annual Survey of Manufacturers, 2019](#)

USDA ["Manufacturing: Food and Beverage Manufacturing", 2021](#)

Food and Beverage Ecosystem



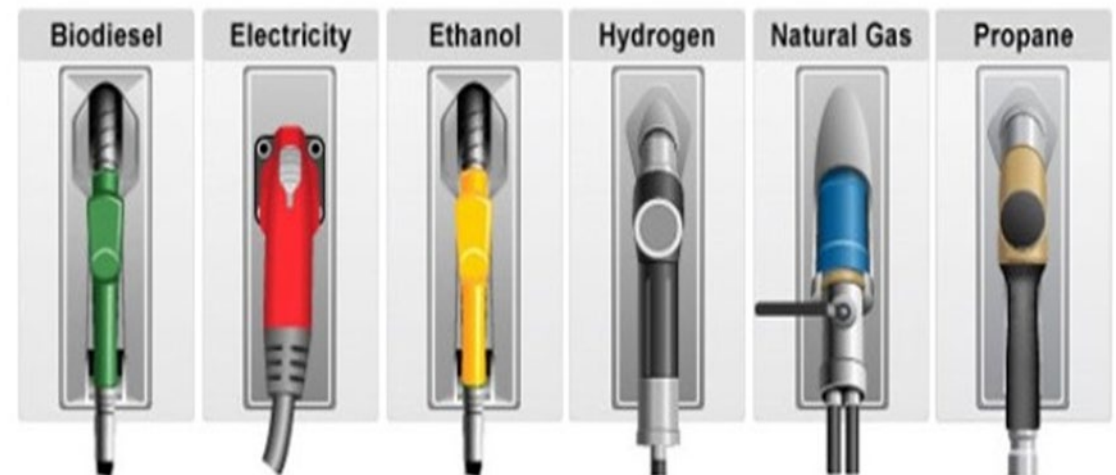
GHG emissions
(estimated)

- Scope 1 (onsite)**
~ 5-10%
 - Scope 2 (purchased)**
~ 5-10%
 - Scope 3 (farming)**
~ 80-90%
- including post-harvesting activities

Trends Affecting the Future of Food System

- U.S. Population Growth
 - 16% projected increase through 2050¹
- FDA Proposed Revisions of “Healthy” on Food Packaging²
 - Aim to reduce diet-related diseases by 2030
 - 80% of population not eating enough vegetables and fruits
- Consumers Preferences³
 - Rethinking the Value Equation:** increased interest in nutritious foods
 - Private Label:** trading down brands for more affordable private labels
 - Consuming Consciously:** sustainability-focused products
 - Plant-Based Products:** 3x growth in sales (2022 versus 2021)
 - Foods for Health:** functional foods in addressing health issues
- Global Food Traceability
- Local Changes in Fuel Mix
- Energy and Water Demand
- Environmental Policies and Compliance Rules
- Urban Expansions
- Sector is expected to grow by ~ 70%⁴

NAICS Code	Total Energy Consumption (tbtu)	Total Fuel Consumption (tbtu)	% Fuel Consumption for CHP/Cogen and Electricity Generation	Total Electrical Consumption (includes fuel consumed for CHP/Cogen and Generation) (tbtu)	Emissions Intensity (MMTCO _{2e} /tbtu)
3116 - Animal Slaughtering and Processing	278	170	30.0%	159	0.082
3112 - Grain and Oilseed Milling	246	196	39.3%	127	0.068
3114 - Fruit and Vegetable Preserving and Specialty Foods	129	95	43.2%	75	0.074
3115 - Dairy Products	122	83	31.3%	65	0.079
3121 - Beverages	111	65	24.6%	62	0.081
311221 - Wet Corn Milling	111	89	50.6%	66	0.065
31131 - Sugar	106	102	37.3%	42	0.051



(1) U.S. Census Bureau, Population Projections for the U.S. 2017-2060
 (2) FDA News Release, Updated Definition of “Healthy Claim”. 2022
 (3) Institute of Food Technologists (IFT), Outlook 2023: Consumer Trends
 (4) American Energy Outlook, 2021

Key Challenges and Barriers

- Conservative industrial paradigm and regulatory hurdles
 - ✓ Most industrial operations **do not want to be the “guinea pigs”**
 - ✓ Compliance (EPA, FDA) - food safety, health, environment impact
- **Cost prohibition** and lack of decarbonization incentives
 - ✓ High CapEx/OpEx and extended payback (ROI, Social ROI)
- Workforce new skills and maintenance **training required**
- Lack of reliable supply chain **infrastructure**
 - ✓ Replacement parts, repair services, vendors, process-demand CO2 supply
- **Customer perceptions** (e.g. food quality, thermal packaging)
- Geographical locations, **smart grid implications** and local specifics
 - ✓ Strict environmental regulations, water scarcity regions
- Scope 2 (energy supply) and Scope 3 emissions (farming)



2050 IEDO Vision: Key Opportunities Across the Pillars

An efficient and competitive industrial sector with net-zero GHG emissions

Energy Efficiency

- ✓ Innovations in Steam Generation and Water Heating
- ✓ Advanced Combustion Processes and Equipment
- ✓ Deep Waste Heat Recovery, Reuse, and Recycle
- ✓ Smart Manufacturing and Modular Onsite Power

Electrification

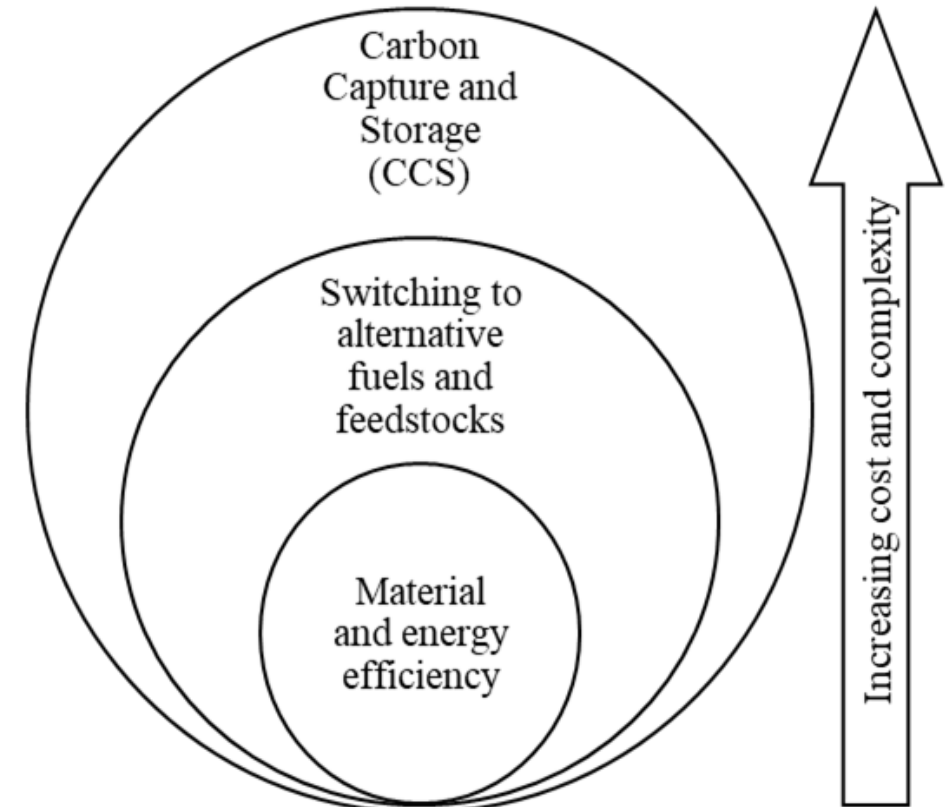
- ✓ Process Heating (induction, resistance, infrared)
- ✓ Advanced Power Electronics
- ✓ Controls and Process Optimization
- ✓ Non-thermal Plasma (GA, DBD, MW, EB)

LCFFES

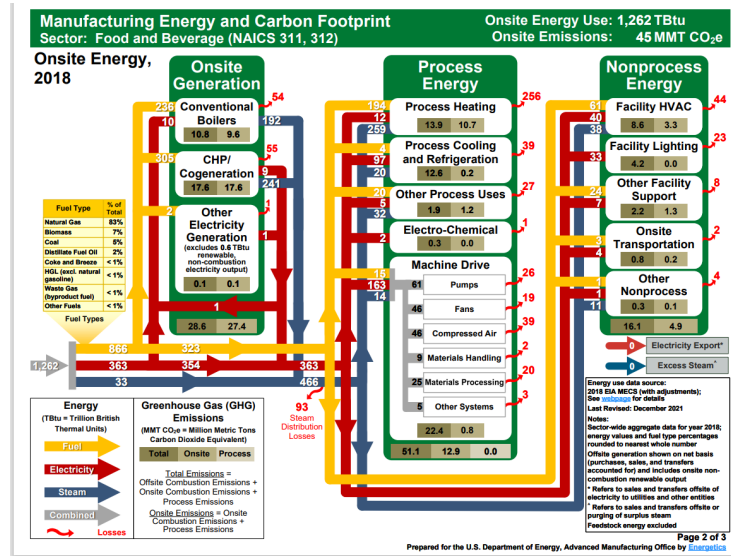
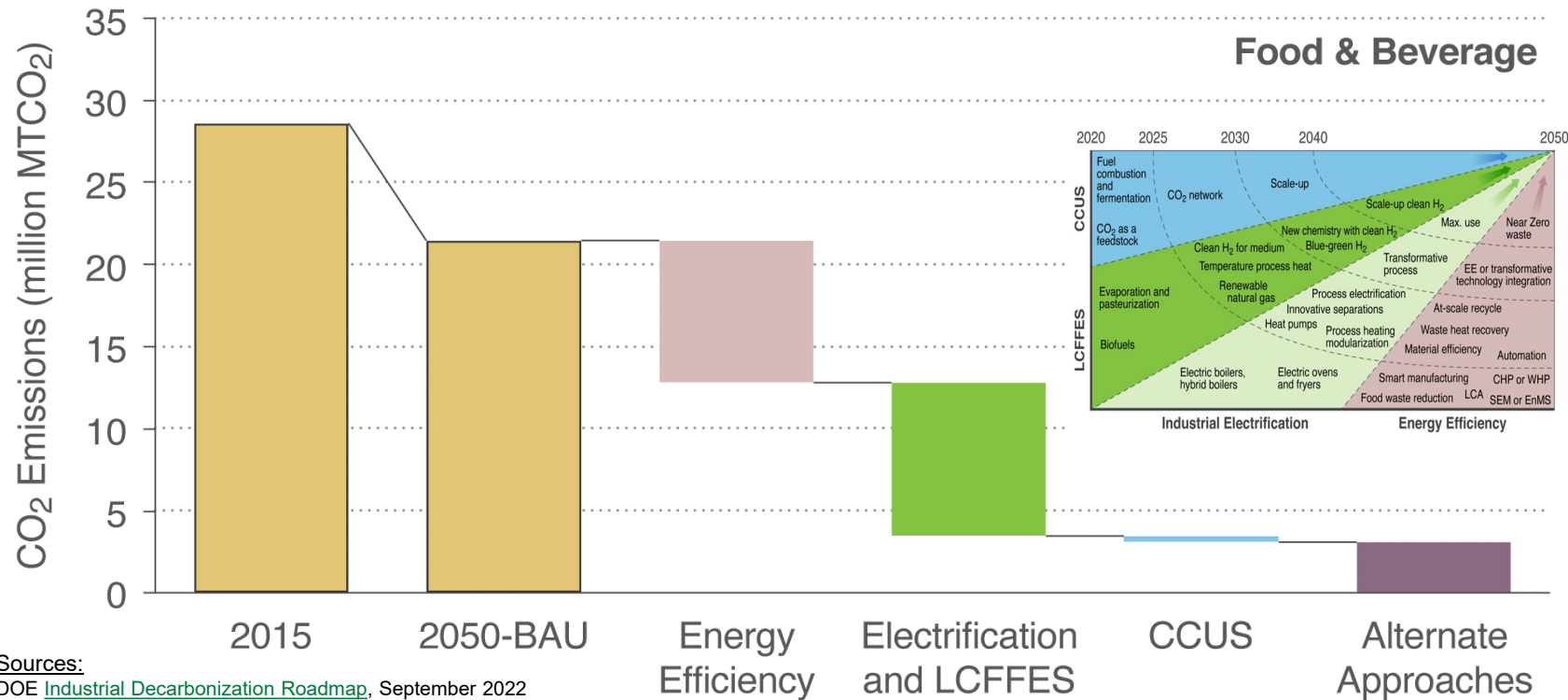
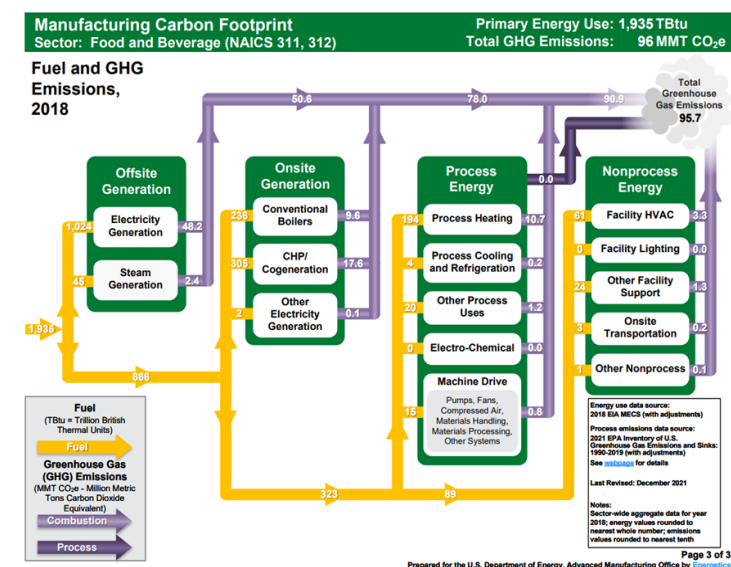
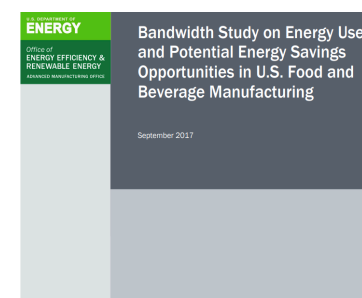
- ✓ Flexible LC/CCHP+ (high P/H ratio, load following)
- ✓ Advanced Solar Assistance and Waste-to-Energy Solutions
- ✓ Alternative Processing (e.g. no CO₂ produced, C₃O₂)
- ✓ Electrofuels and Ammonia (e.g. H₂ blends, e-Combustible)

CCUS

- ✓ Carbonated beverages, dry ice, cooling and refrigeration, refining and packaging, stunning, etc.

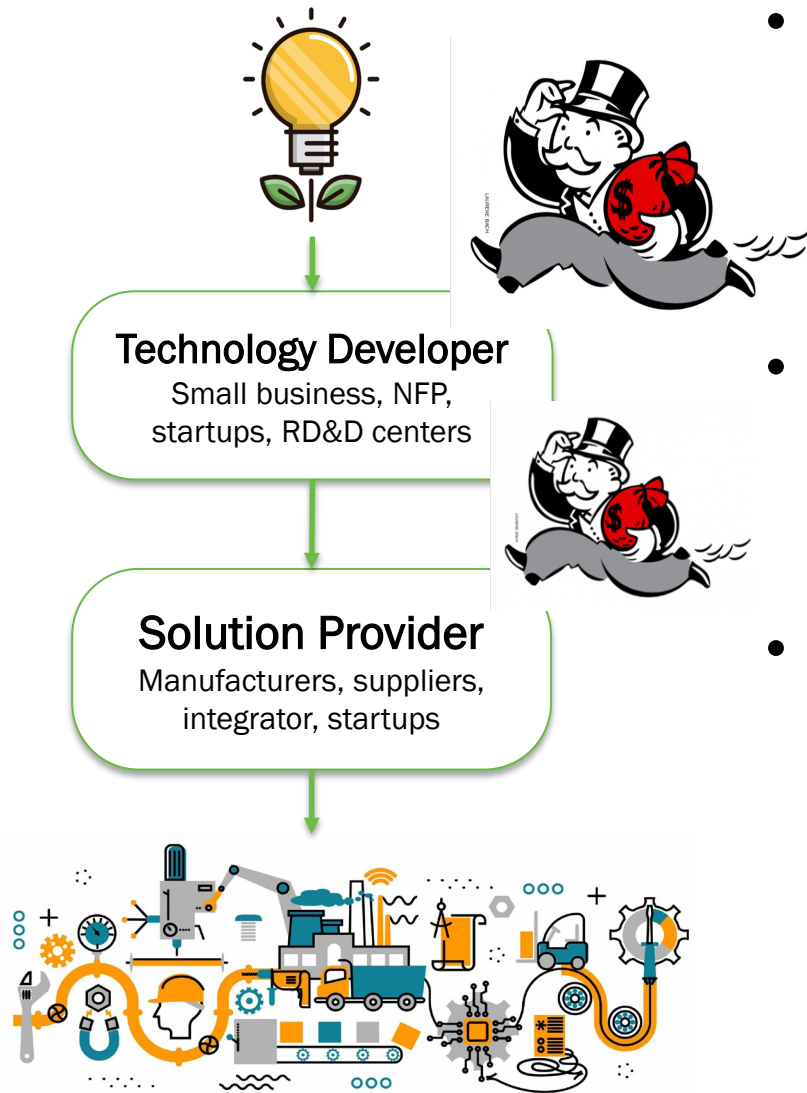


Impact Analysis and 2015-2050 Decarbonization Forecast



Sources:
DOE [Industrial Decarbonization Roadmap](#), September 2022
AMO [Thermal Process Intensification report](#), May 2022
AMO [Bandwidth Study U.S. Food and Beverage Manufacturing](#), December 2017
ORNL [Technology Assessment on Low-Temperature Waste Heat Recovery in Industry](#), September 2021

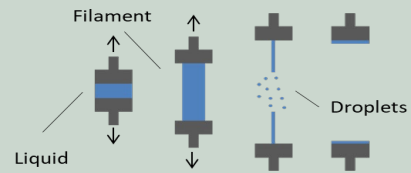
IEDO/EEII Strategy to Achieve F&B Decarbonization Targets



- Focus on innovative and transformational concepts
 - TRL3(4) through TRL6(7) along with compelling lifecycle analysis
 - Multi-scale spectrum of technology demonstrations (laboratory, pilot, field)
 - Target commercialization across the prioritized areas by 2030
 - Proven decarbonization impact (> 85% GHG reduction)
- Stakeholder engagement activities
 - Site visits and roundtables to refine the challenges and priorities
 - Accelerate adoption of decarbonization technologies (EEII/TAWD)
 - Food manufacturers, equipment manufacturers, technology developers
- Active collaboration on industrial decarbonization agenda
 - U.S. DOE offices: BETO, AMMTO, SETO, FECM, HFTO, OCED, ARPA-E
 - National laboratories and strategic analysis teams
 - Industrial Decarbonization Roadmap Extension project
 - USDA: Climate-Smart Partnership \$1B+, Indoor Farming, Post-Harvest
 - State Energy Offices
 - CEC (IAW Program, FPIP \$100M+)
 - NYSERDA, Oregon DEQ, SCAQMD and others

EEl Food and Beverage Budget and Portfolio

Energy- and Emissions-Intensive Industries	FY 2023 Enacted Budget	FY 2024 Requested Budget
Chemical, Forest Products and Related Industries	\$40,000,000	\$60,000,000
Iron, Steel and Other Metal Industries	Support industrial decarbonization activities, including RD&D with focus on the chemicals, iron and steel, cement, and food products industries	For food manufacturing , pursue RD&D to evaluate a suite of electrification technologies for drying, dewatering and heating for energy-and carbon-intensive food production processes
Cement, Food Products and Other Industries		

Project Samples	Technology Approach	Application Focus	Progress and Status
Palo Alto Research Center Team: Utah State University Darigold Leprino Tetra Pak	Filament extension atomization 	Whey protein and other food powders, including fruits, vegetables, and synthetic meat Efficiency increase by up to 40% Cost reduction ~ 40-70% GHG emissions reduction by 50%	Multinip array has been commissioned. Achieved: <ul style="list-style-type: none"> 72 hours of runtime (target 72) Sprayed 4.7 L/m of whey product (target 2.5) Harvested at 2.5 L/m of whey product (target 2.5) Further scaling spray system to 7.5 L/m and integration with dryer design is underway
Worcester Polytechnic Institute (CARD) Team: UIUC, ORNL	Di-electrophoresis, acoustic and ultrasonic drying, impinging slot jet nozzle, smart sensors and AI controls	Fruits and vegetables (sliced apples, vegetables, chips, potato powder, etc.) Efficiency increase by 25-35%	Smart dryer testbed was commissioned in October 2022 Adjustments and calibration are in progress Integration and performance testing Q2/Q3-2023
Controlled Environment Agriculture (SBIR) Multiple projects	CEA to develop local capacity and achieve optimal growth conditions of crops by optimizing water, energy, space	Multiple focus ranging from energy efficiency of community food production to wastewater management and recycling	SBIR Phase 1 has been completed SBIR Phase 2 awards pending selection CEA Accelerator (via lab call) award pending selection

FOA-0002804 (FY22)

- AOI – Low Carbon Process Heating
- Full Application review completed
- Award selection pending

FOA-0002997 (FY23)

- AOI – Low- and Zero-Carbon Solutions for Process Heating and Cooling
- Full Applications due by 6-23-2023

FY24 Program Planning

- Advanced energy efficient separations
- Alternative proteins
- Deep heat and water recovery (> 50%)

Upcoming Work to Maximize the Impact

There is no one stakeholder solely representing the entire U.S. Food and Beverage Industry

- **FY23 Stakeholder Engagement Workshop**
 - Industry-wide workshop with focused sessions to facilitate the discussion and collection of candid perspectives from industry producers, technology providers, trade associations, utilities companies, and academic institutions
 - Tentatively scheduled for Q4 FY23
- **FY24 Planning**
 - Define the F&B sector boundaries within the U.S. Food System
 - Assess the quantity and quality of applications submitted to FY22/FY23 FOAs
 - Conduct key stakeholder outreach activities to refine the investment priorities
 - Refine the FY24 budget request and identify:
 - The most impactful energy efficiency measures across the Food and Beverage sector
 - The highest energy consumers and the largest GHG emitters
 - The opportunity fuel mix for maximum impact
 - Formulate the top priorities for FY24 Multi-Topic FOA
 - Other investment activities (SBIR/STTR, interagency efforts)



Questions? Comments? Concerns? Suggestions?

Our Mission:

IEDO leads the development and accelerates the adoption of sustainable technologies that increase efficiency and eliminate industrial GHG emissions

