U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Bioenergy Technologies Office: Technology Update and Investment Strategy

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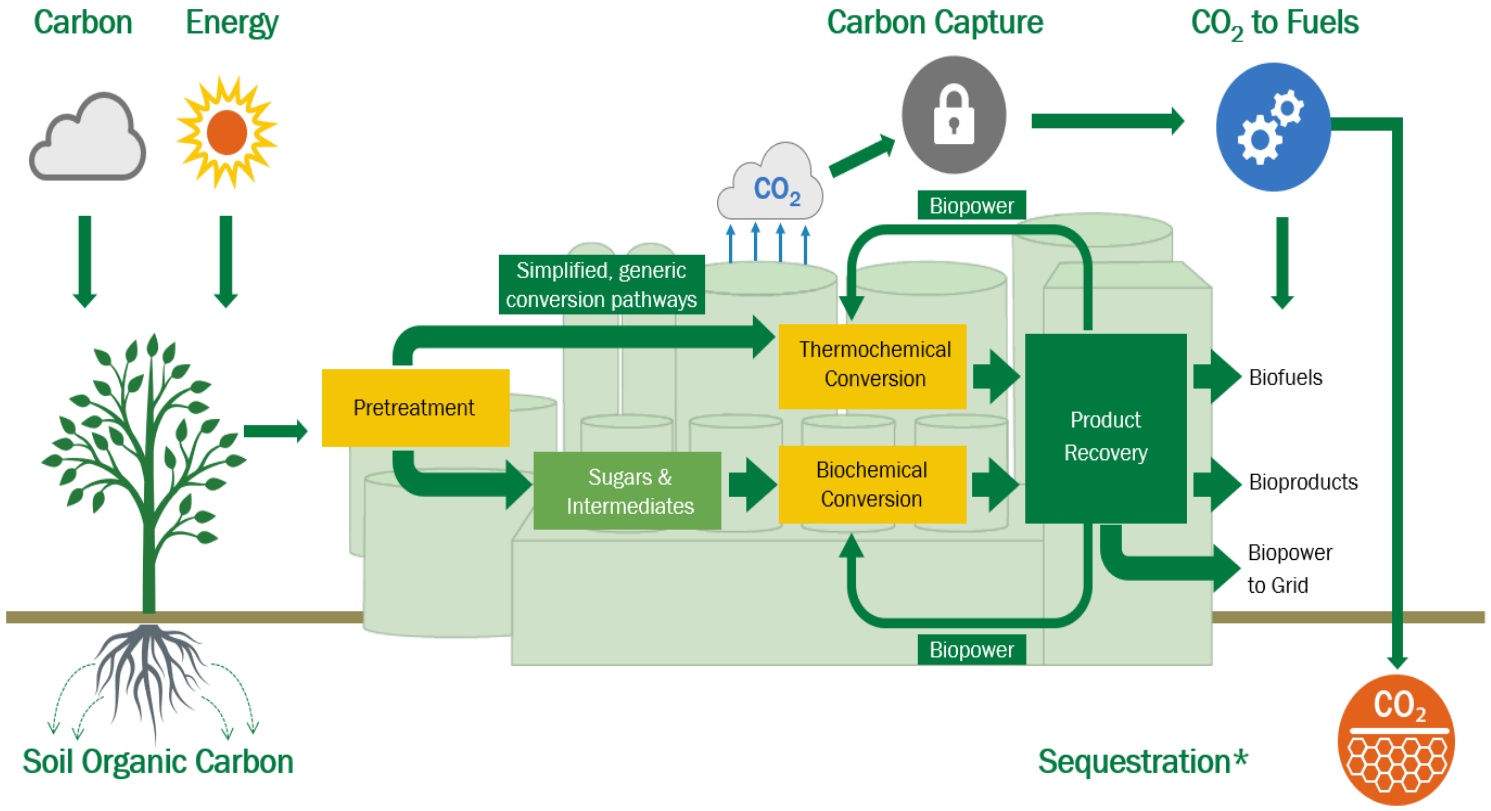
3/ZZ/22

Agenda

- Understanding Bioenergy and Its Decarbonization Potential
- Biomass Feedstocks: Broad U.S. Potential
- State of the Bioenergy Industry Today and Our Strategy for Success

Biomass: Nature's Carbon Removal Technology (for 3.4 Billion Years)

- **Biomass** includes food waste, municipal solid waste, agricultural and forest wastes, animal wastes, and energy crops.
- **Bioenergy** is the conversion of biomass to energy that can replace fossil fuels.



** Office of Fossil Energy R&D on technologies of relevance to bioenergy industry.*

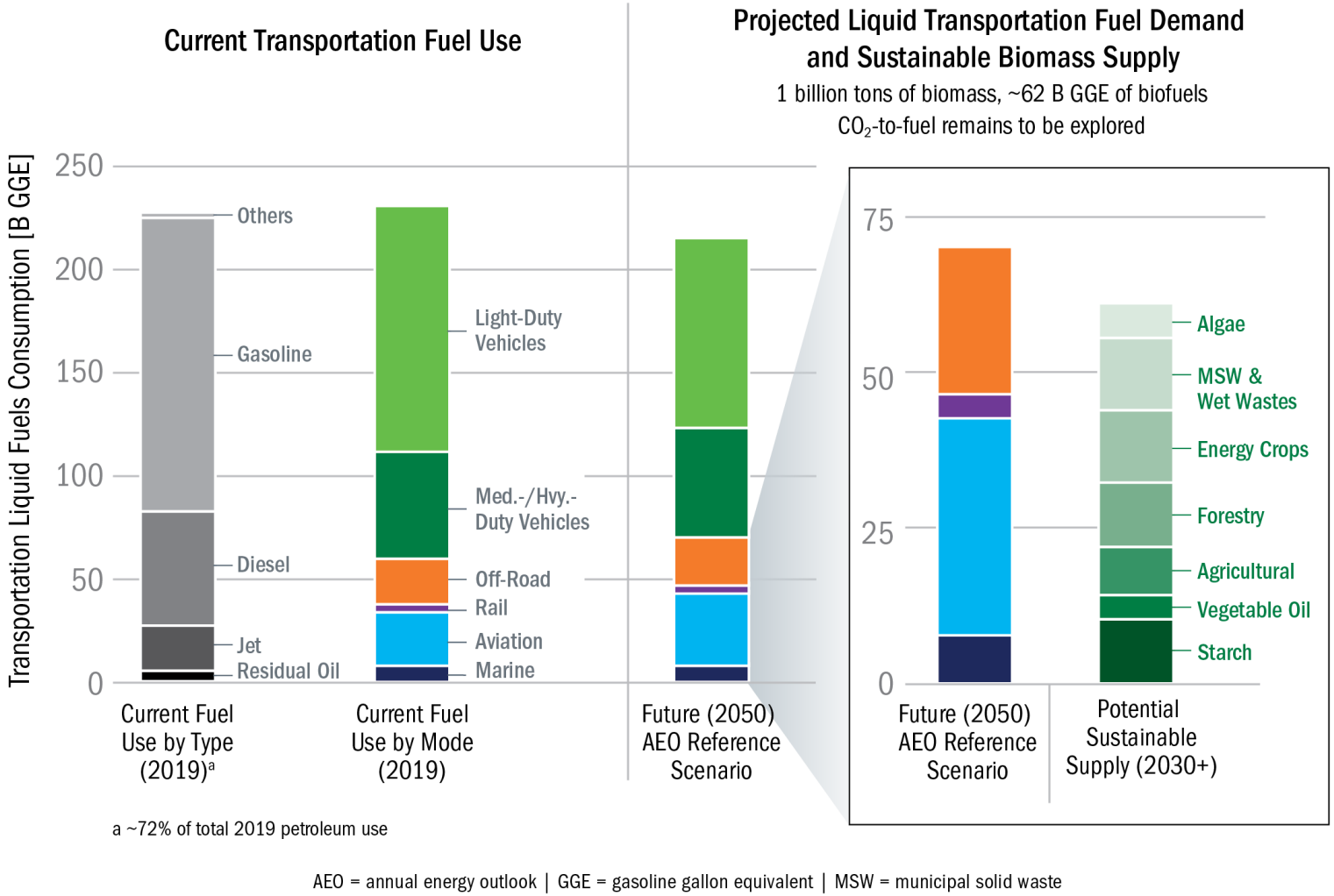
Bioeconomy: An economy based on products, services, and processes derived from biological resources (e.g., plants and microorganisms) and encompassing multiple sectors.

Bioenergy is a key component of the U.S. bioeconomy and contributor to ***decarbonizing transportation, industry, and agriculture***.

The Role of Biomass in Sustainable Transportation

- Transportation accounts for 34% of U.S. greenhouse gas (GHG) emissions.
- Biofuels are part of a sustainable transportation fuel strategy to decarbonize all modes.
- U.S. biomass can meet the needs of "hard to electrify" modes, such as aviation, marine and rail.

Focus areas for biofuels:
- Ethanol for passenger cars
- "Drop-in" fuels that can use existing infrastructure such as renewable diesel/sustainable aviation fuels

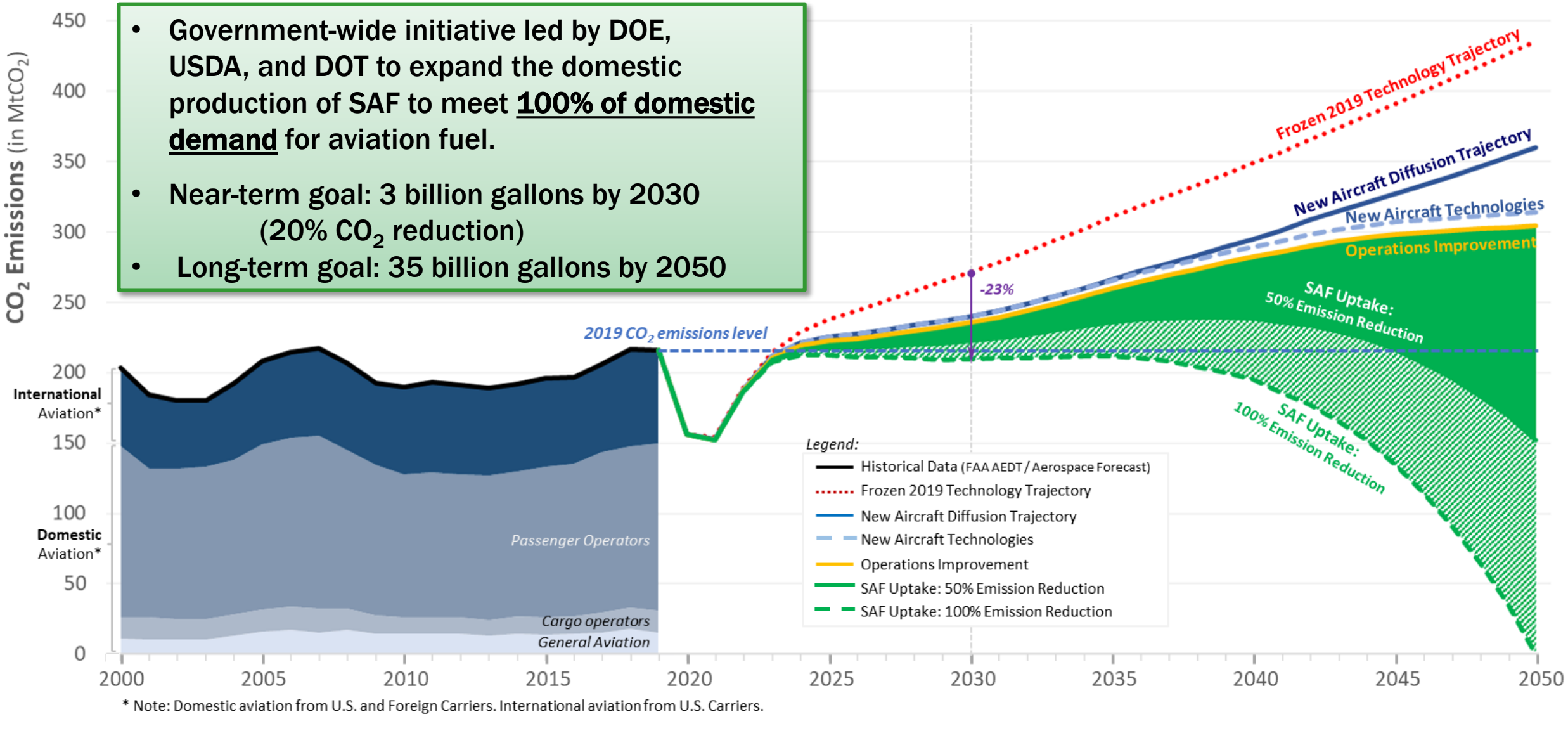


a ~72% of total 2019 petroleum use

AEO = annual energy outlook | GGE = gasoline gallon equivalent | MSW = municipal solid waste

Sustainable Aviation Fuel (SAF) Grand Challenge

- Government-wide initiative led by DOE, USDA, and DOT to expand the domestic production of SAF to meet **100% of domestic demand** for aviation fuel.
- Near-term goal: 3 billion gallons by 2030 (20% CO_2 reduction)
- Long-term goal: 35 billion gallons by 2050

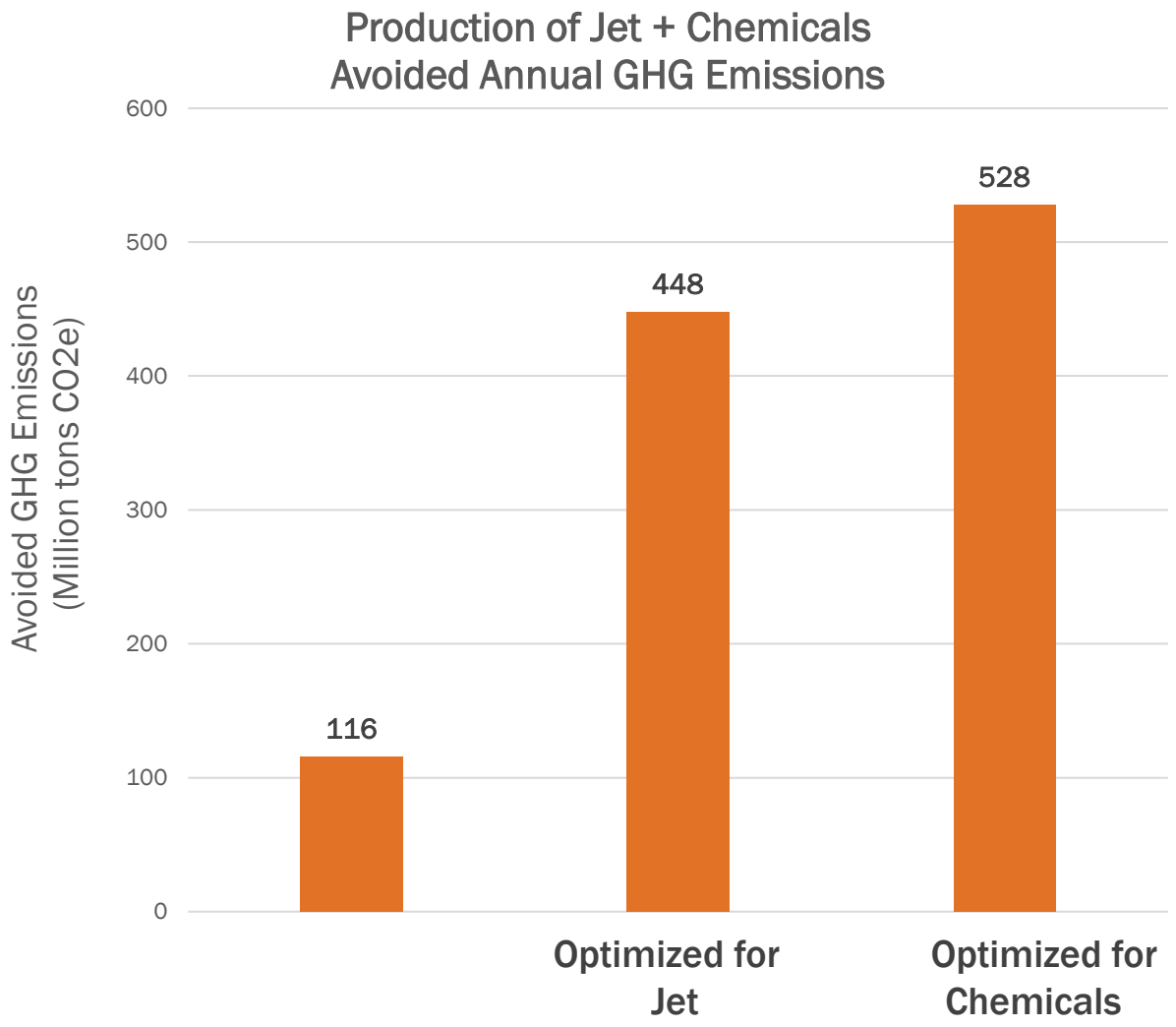


* Note: Domestic aviation from U.S. and Foreign Carriers. International aviation from U.S. Carriers.

The Role of Biomass in Industry

- Chemical production accounts for 5.5% of U.S. GHG emissions.
- Biomass is the only renewable resource that can replace petroleum to make carbon-based chemicals.
- Biomass-derived chemicals could significantly reduce GHG emissions.

Focus areas
- Drop-in replacements for petro-chemicals
- Performance enhanced biochemicals
- Recyclable on demand

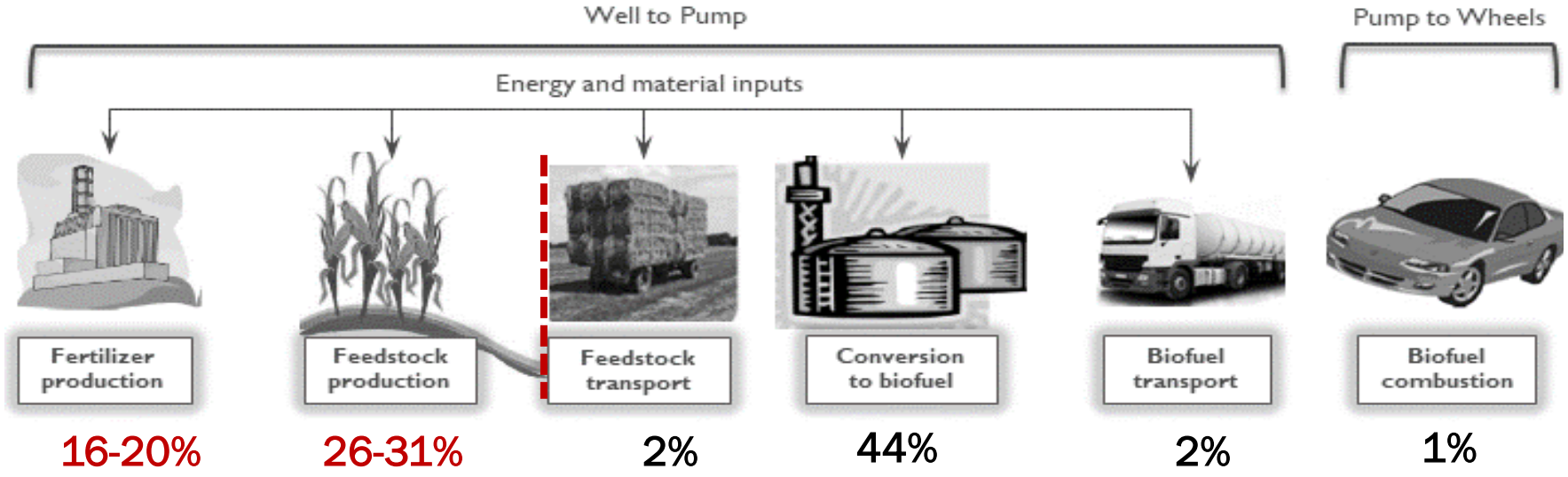


The Role of Biomass in Agriculture

- Agriculture activities serve as sources and sinks for GHGs.
- Decarbonizing transportation/chemicals and decarbonizing agriculture are intrinsically linked.
- By developing tools and strategies to quantify and improve soil carbon sequestration and ecosystem services, we can produce biofuels with a lower carbon intensity.

Focus areas in agriculture:

- Maximize soil CO_2 sequestration by developing healthy, productive soils and regenerating distressed soil.
- Develop climate-smart ag practices.
- Produce clean energy on-site from animal waste.
- Develop wastewater treatment strategies that produce bioenergy feedstocks.



Argonne Final Report to ARPA-E (2019): *Developing a Framework for Lifecycle Analysis of Biofuels on the Farm Level*

Benefits of a Bioeconomy

Across the United States, a bioeconomy will:

- Create jobs in agriculture, waste management, transportation, manufacturing, construction
- Invest in communities and help manage waste disposal, creating new revenue streams
- Reduce methane emissions associated with waste disposal
- Produce clean water and reduce fertilizer use in agriculture
- Achieve lasting carbon reductions across the U.S. economy

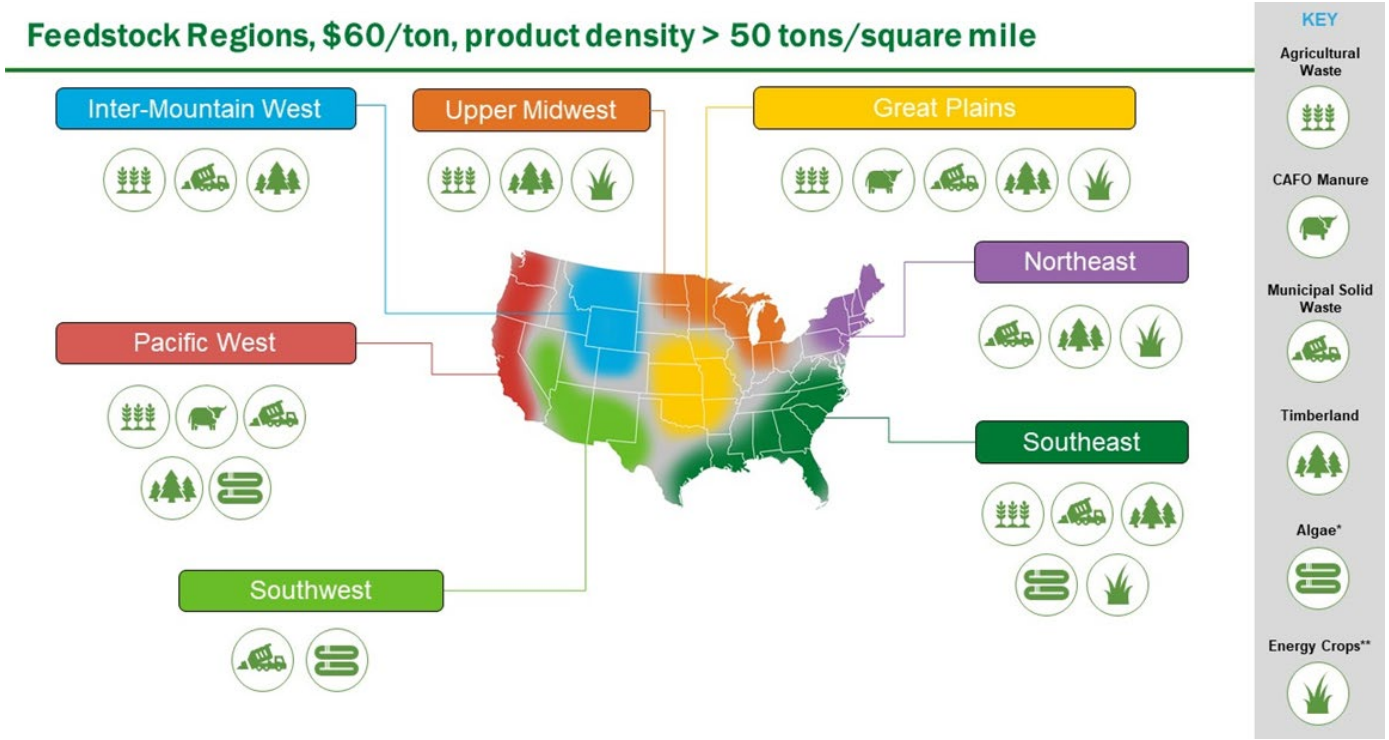
Photo courtesy of FDC Enterprises

Agenda

- Understanding Bioenergy and Its Decarbonization Potential
- **Biomass Feedstocks: Broad U.S. Potential**
- The State of the Bioenergy Industry Today and Our Strategy for Success

Biomass is Widely Available

- The U.S. has the potential to produce 1 billion tons of sustainable biomass annually.
- About 645 million tons of biomass is needed to make 35 billion gallons of SAF annually.
- No single resource type is sufficient on its own to meet demand.
- A diversified feedstock supply will:
  - Deliver economic and environmental benefits across the U.S.
  - Increase resilience across the supply chain.



*Saline, current productivities, minimally lined saline ponds, co-location with CO_2 from coal, natural gas, and ethanol plants at prices from $755-$2,889 per dry ton ($2014)
**Energy crops derived from 2040 dataset, all other biomass from 2017 dataset

Anticipated Resource Availability Over Time

2021-2025

Fats, oils, and greases

Corn/corn ethanol

2026-2030

MSW and wood waste

2030-2040

Ag wastes

2040-2050

Energy crops and algae

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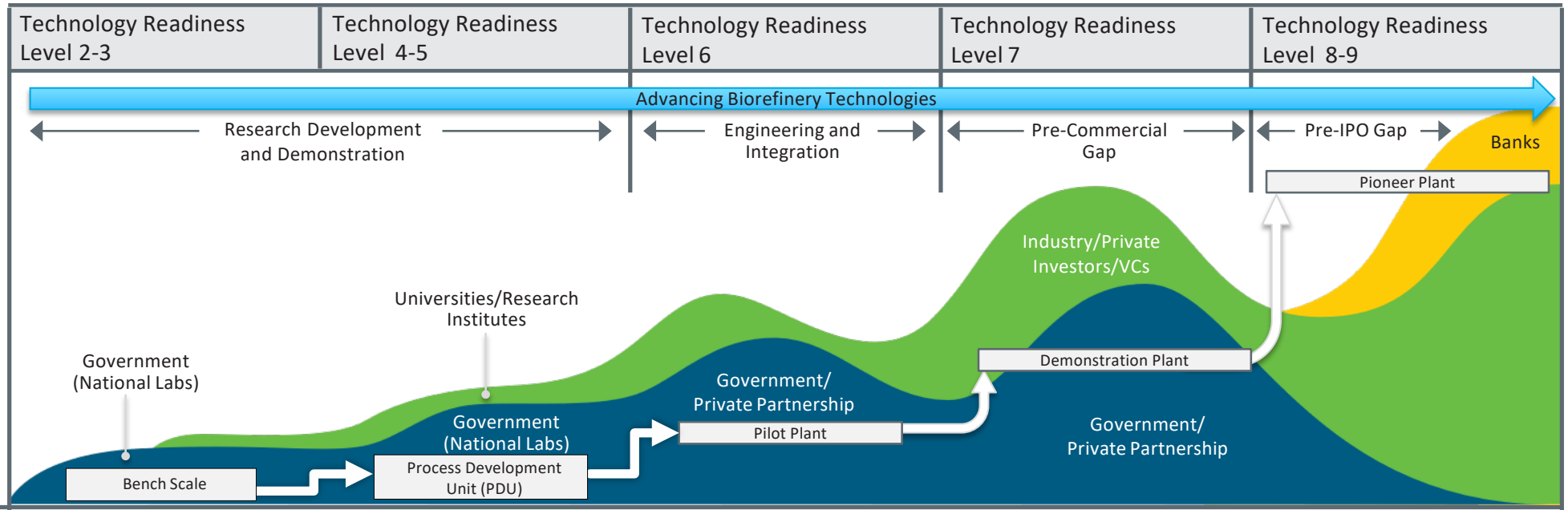
BETO Invests in Applied R&D and Large-Scale Demonstration



Average Total Project Cost	$1–$5 Million	$5–$10 Million	$25–$50 Million	$100–$500 Million	$250–$500 Million
Average Biomass Throughput	Grams/Day	Kilograms/Day	<50 Tonnes/Day	50–250 Tonnes/Day	+250 Tonnes/Day
Production Volumes	mL/L (batch)	Liters/Gallons (batch)	0.1–1 M GPY (campaign)	1–10 M GPY (extended campaign continuous)	50 M GPY (continuous)

Government Project Recipients and Partners Banks

From Strain Development to Commercial Operation

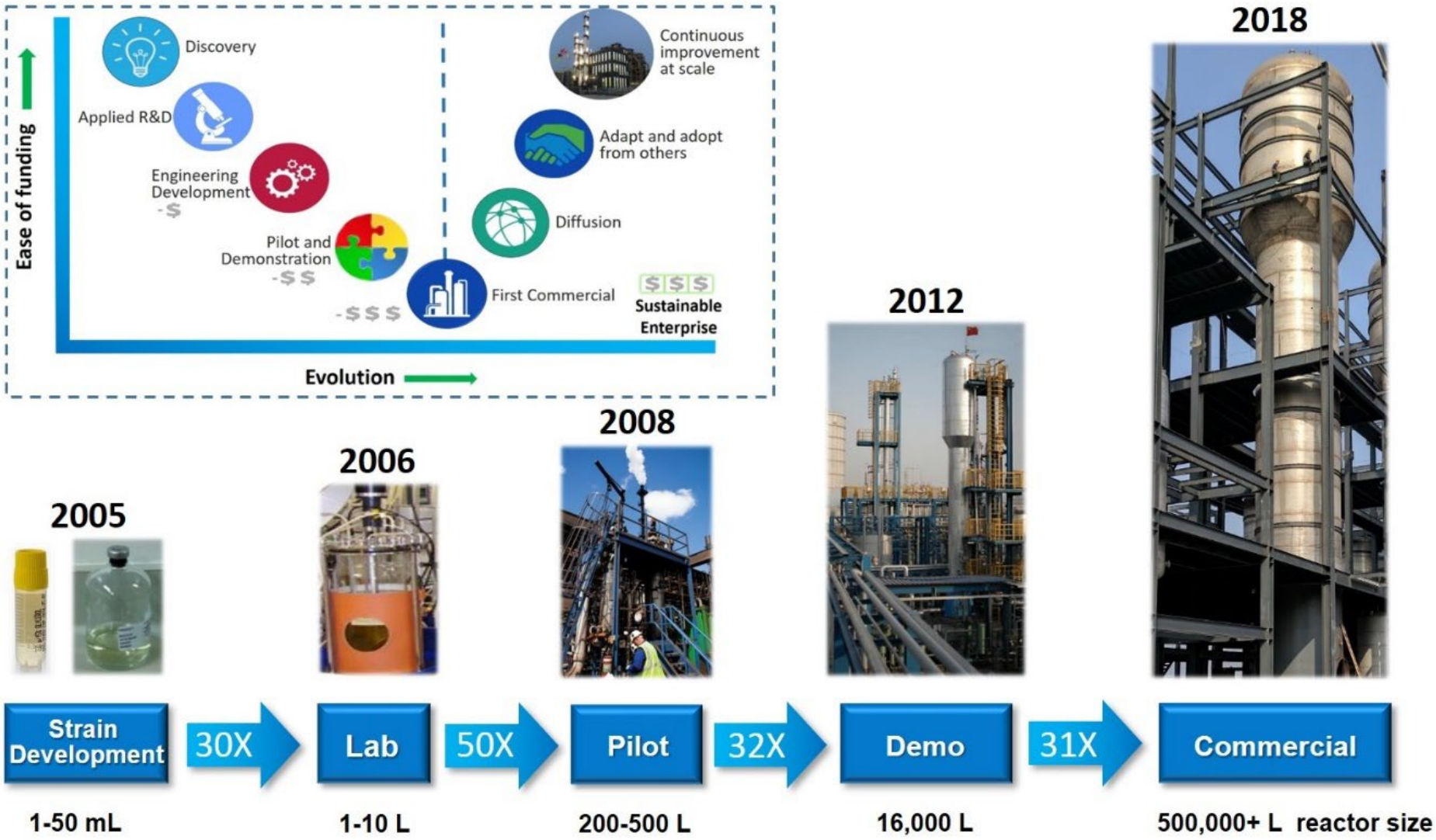


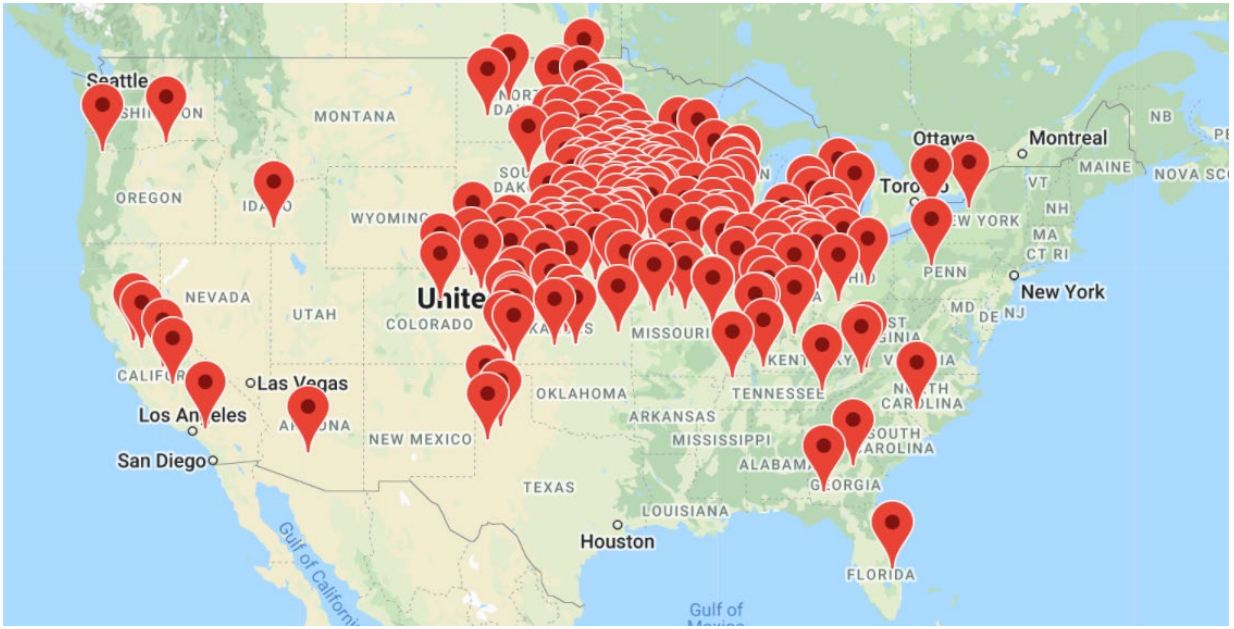
Image courtesy of LanzaTech

The State of the Industry

URGENT: **Expand** the emerging industry

- TODAY: **~5 million gallons/year SAF production**
- BY 2030: **Double SAF production in 2028 and 2029 to meet the 2030 goal**
  - Construct 15 biorefineries and produce over 800 million gallons by 2027
- BY 2050: **35 billion gallons, meeting 100% of aviation fuel demand**
  - 400–500 refineries in the U.S.
  - More than double today's fuel ethanol industry

Doubling the Number of Biorefineries



- Ethanol industry grew from 2 billion gallons/year in 2002 to nearly 16 Billion gallons in 2016
- There are about 215 ethanol refineries in the U.S. built over 15 years, primarily in the Midwest.

- The U.S. will need:
  - 40-45 refineries by 2030
  - 400-500 refineries by 2050

Bioenergy Technologies – FY 2023 Request

Bioenergy Technologies develops and demonstrates technologies to accelerate greenhouse gas emissions reductions through the cost-effective, sustainable use of biomass and waste feedstocks across the U.S. economy.

Subprogram (in thousands)	FY 2022 Enacted	FY 2023 Request	FY 2023 vs. FY 2022	% Change
System Development and Integration	70,500	152,500	+82,000	+116.3%
Feedstock and Algal System Technologies	82,000	68,000	-14,000	-17.1%
Conversion Technologies	100,000	110,000	+10,000	+10.0%
Data, Modeling and Analysis	9,500	9,500	0	0.0%
Total	**262,000**	**340,000**	+78,000	+29.8%

FY 2023 Emphasis Areas

- *Decarbonizing Transportation:* Scale-up in support of SAF Grand Challenge; Continued efforts to reduce CO_2 emissions at "traditional" ethanol biorefineries; New biofuel pathways to marine, rail, and other hard-to-decarbonize modes of transportation
- *Decarbonizing Agriculture:* Climate Smart Agriculture and Soil Carbon; Rural Organic Waste Pilots
- *Decarbonizing Industry:* Continued development of valuable chemicals and materials that can replace petrochemicals with renewable alternatives

Key Takeaways

- Biomass can play a significant role in decarbonizing several sectors of the economy.
- Biomass can create good jobs, economic opportunities, and environmental benefits for all states and regions in the U.S.
- Near-term deployment is driven by strong market pull.
- Continued investments in technology R&D and scale-up demonstration are needed to ensure access to all feedstocks in all regions and meet decarbonization goals
  - Including goal of meeting **100% of domestic demand** for aviation fuel with SAF.
- Strong sustained policies are necessary to accelerate investments.