

Bioenergy Solutions for Hard to Electrify Sectors

Valerie Reed, Ph.D.

Director, Bioenergy Technologies Office

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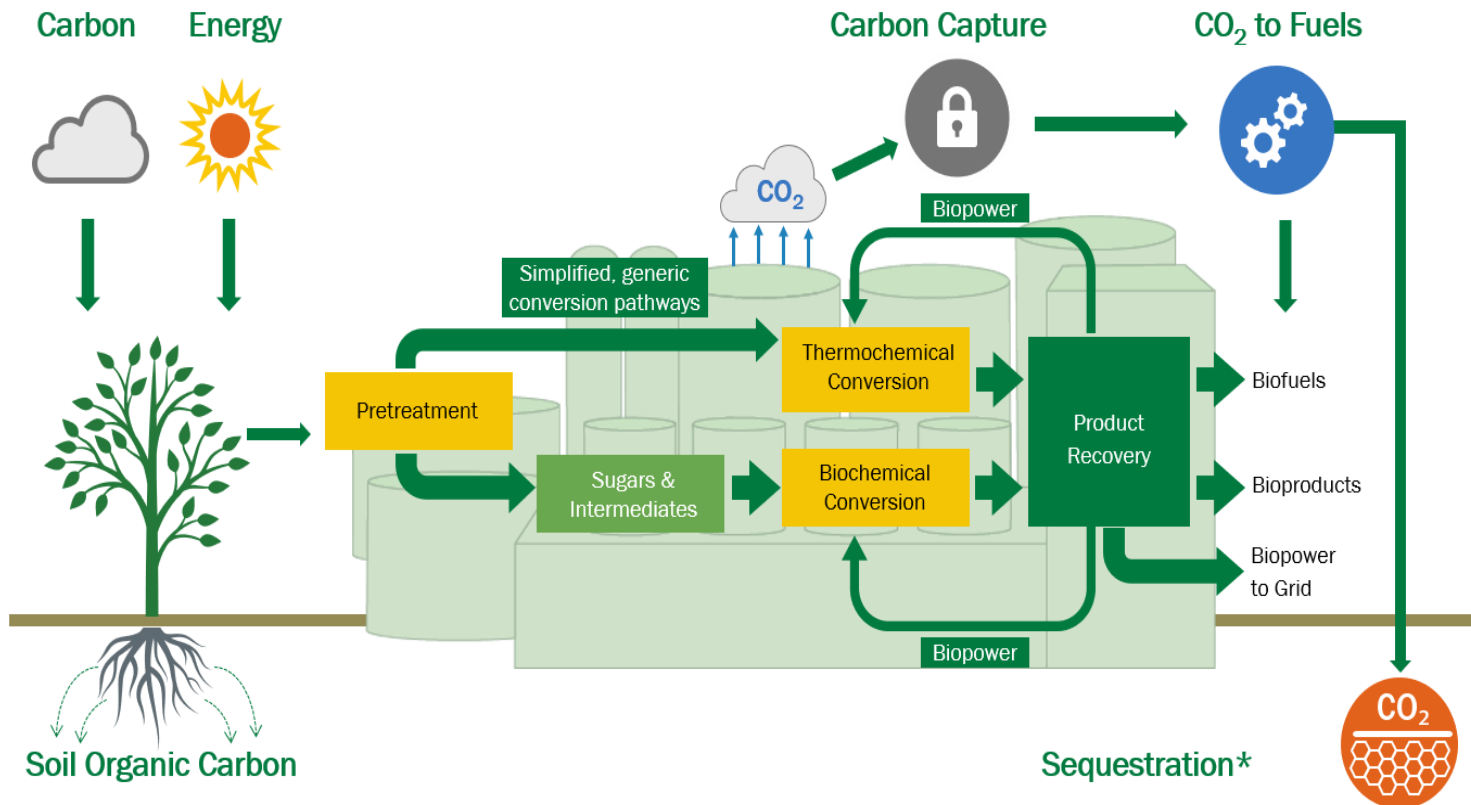


Agenda

- 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.

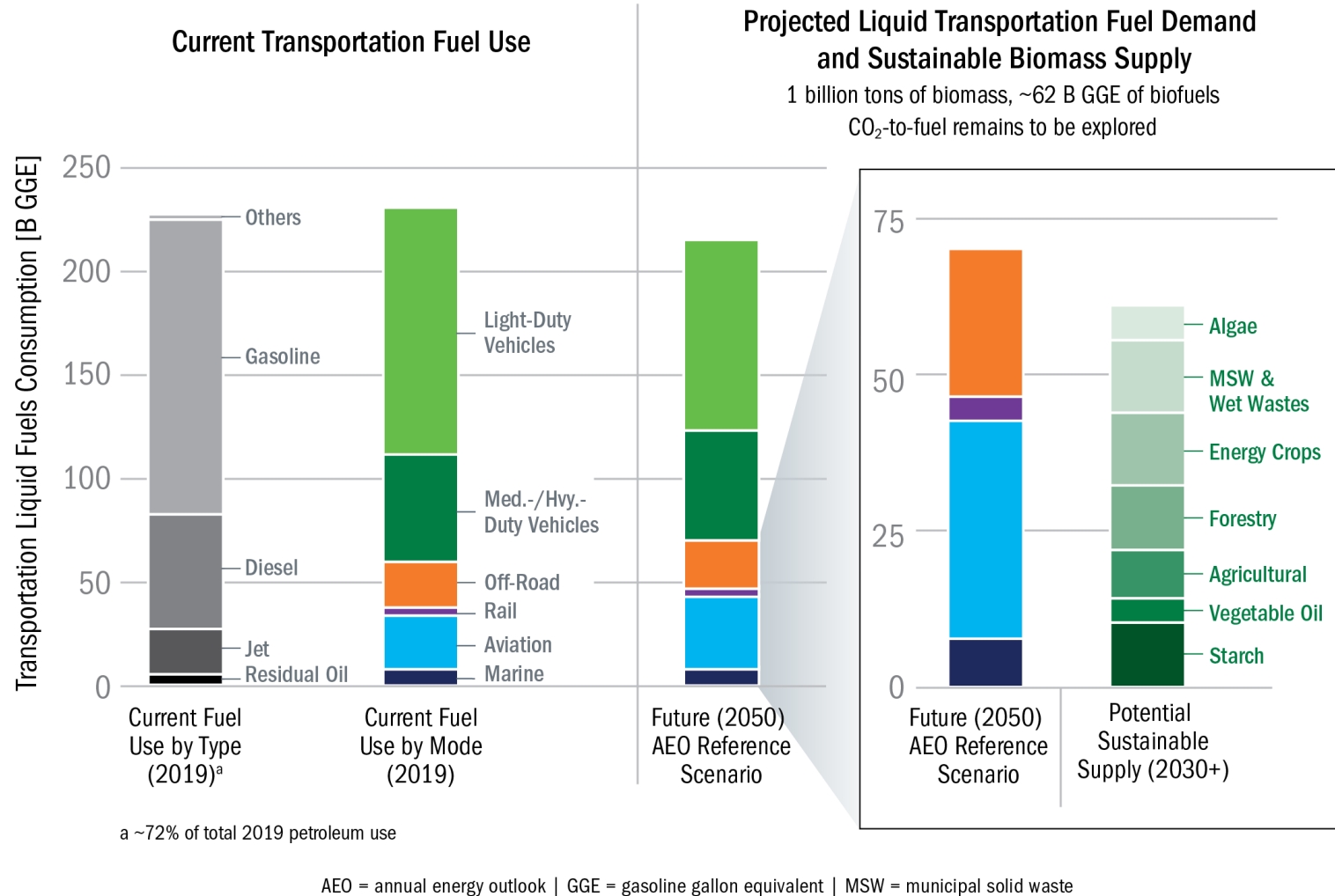
Bioenergy is a key component of the U.S. bioeconomy and contributor to *decarbonizing transportation, industry, and agriculture.*

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.

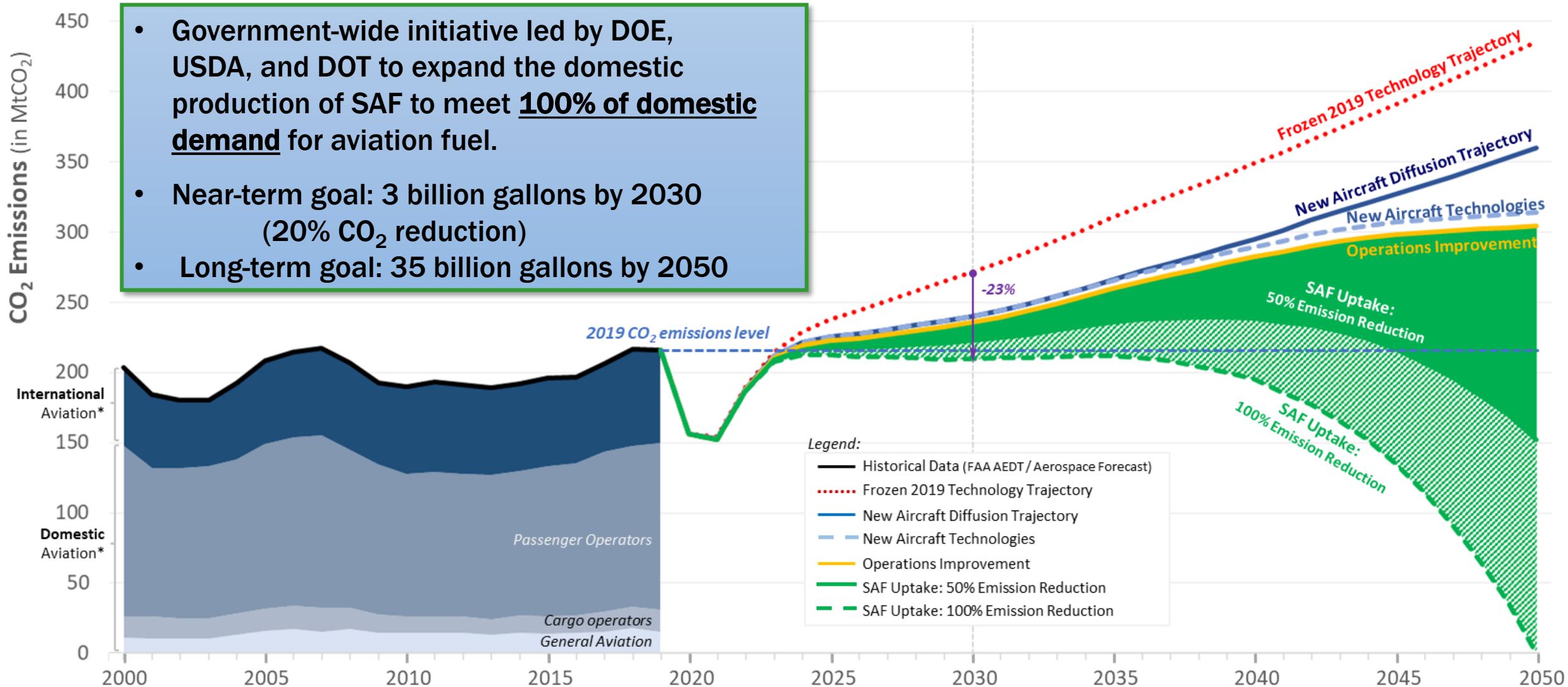
Focus areas for biofuels:

- **Ethanol for passenger cars**
- **“Drop-in” fuels that can use existing infrastructure such as renewable diesel/sustainable aviation fuels**



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% CO₂ reduction)
- Long-term goal: 35 billion gallons by 2050



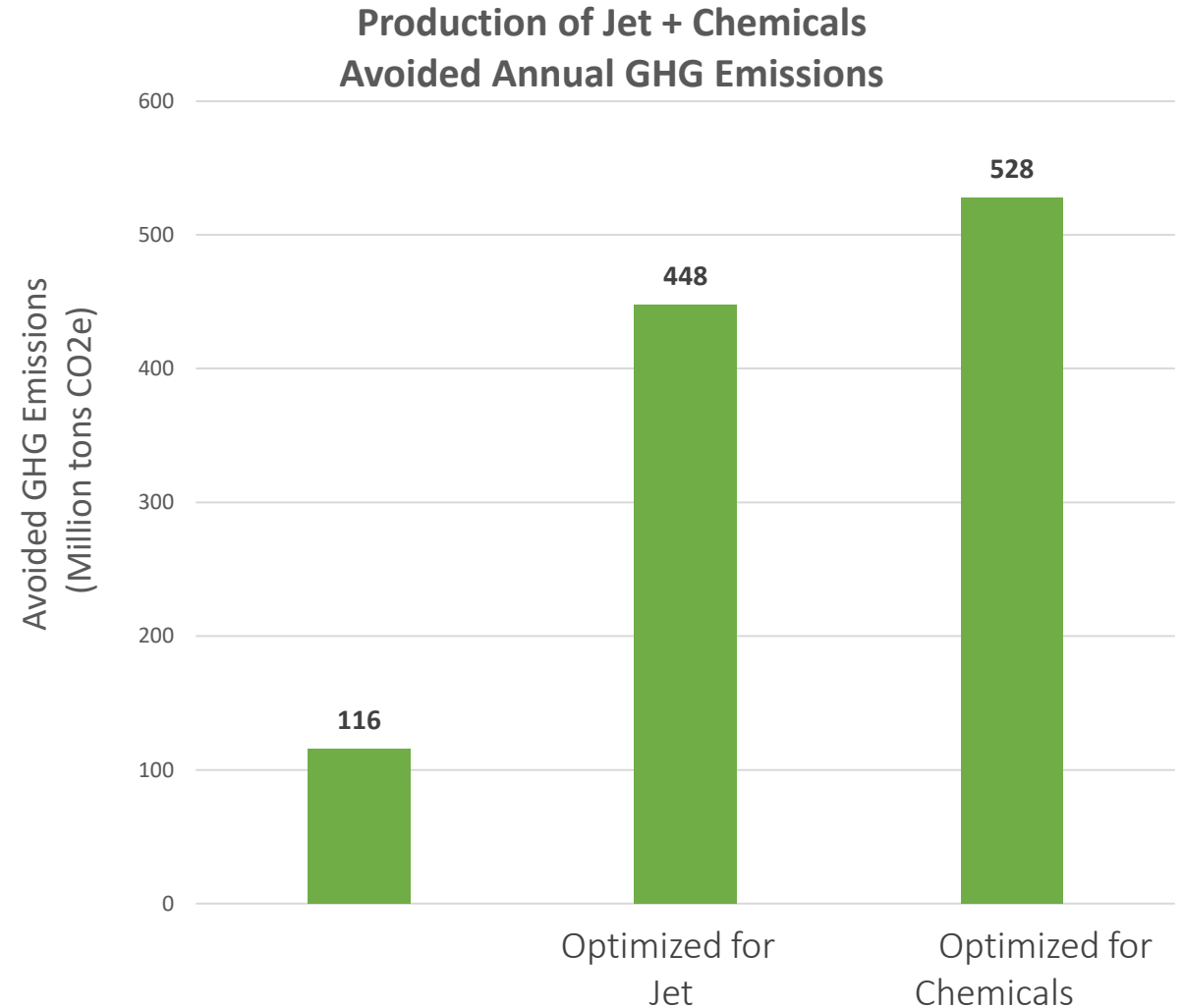
* Note: Domestic aviation from U.S. and Foreign Carriers. International aviation from U.S. Carriers.

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**



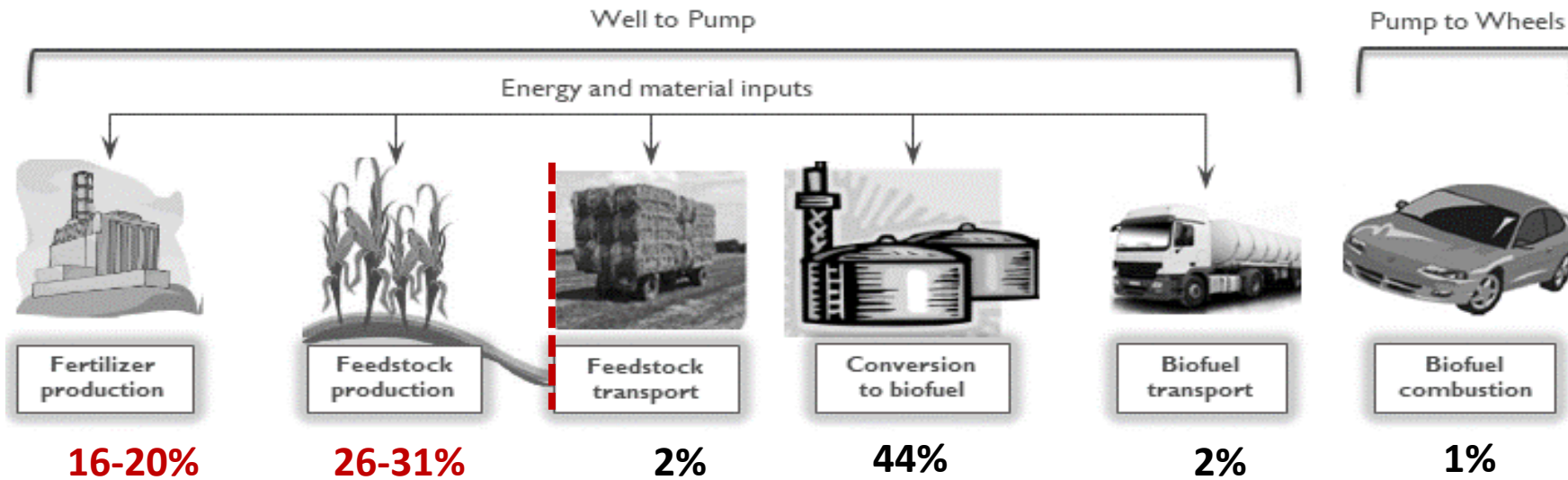
The Role of Biomass in Agriculture

- 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 CO₂ 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.

**Emissions
Contribution**



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:

- Already reducing GHG emissions and used for transportation
- 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

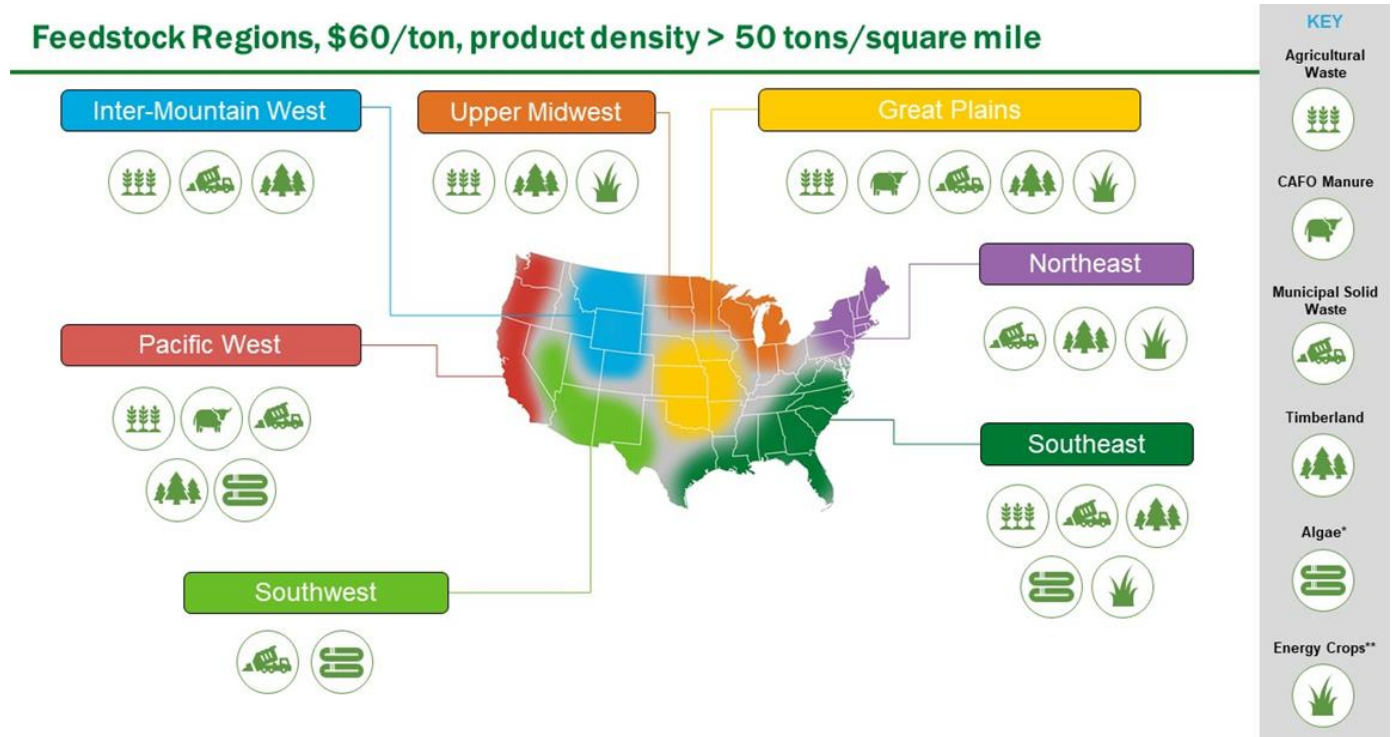


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Biomass is Widely Available

- 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.



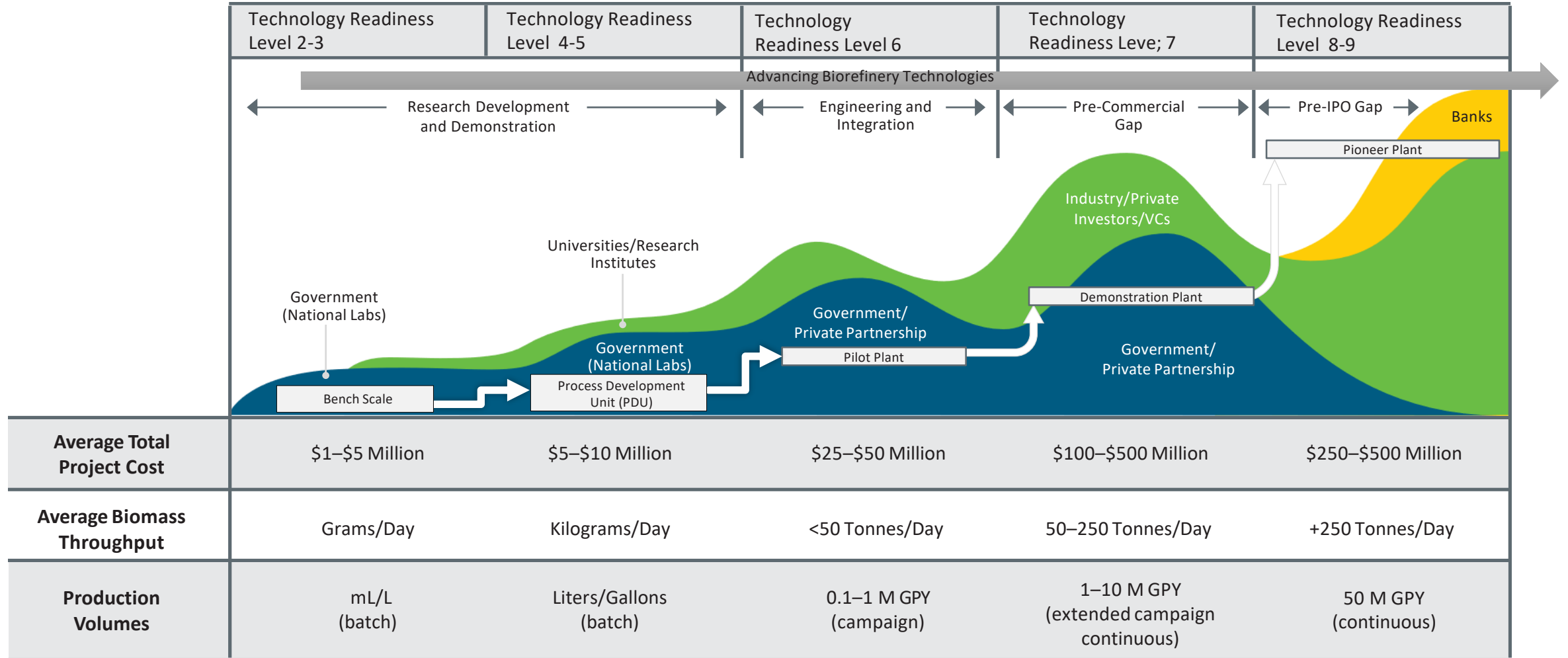
*Saline, current productivities, minimally lined saline ponds, co-location with CO₂ from coal, natural gas, and ethanol plants at prices from \$755-\$2,889 per dry ton (\$2014)

**Energy crops derived from 2040 dataset, all other biomass from 2017 dataset

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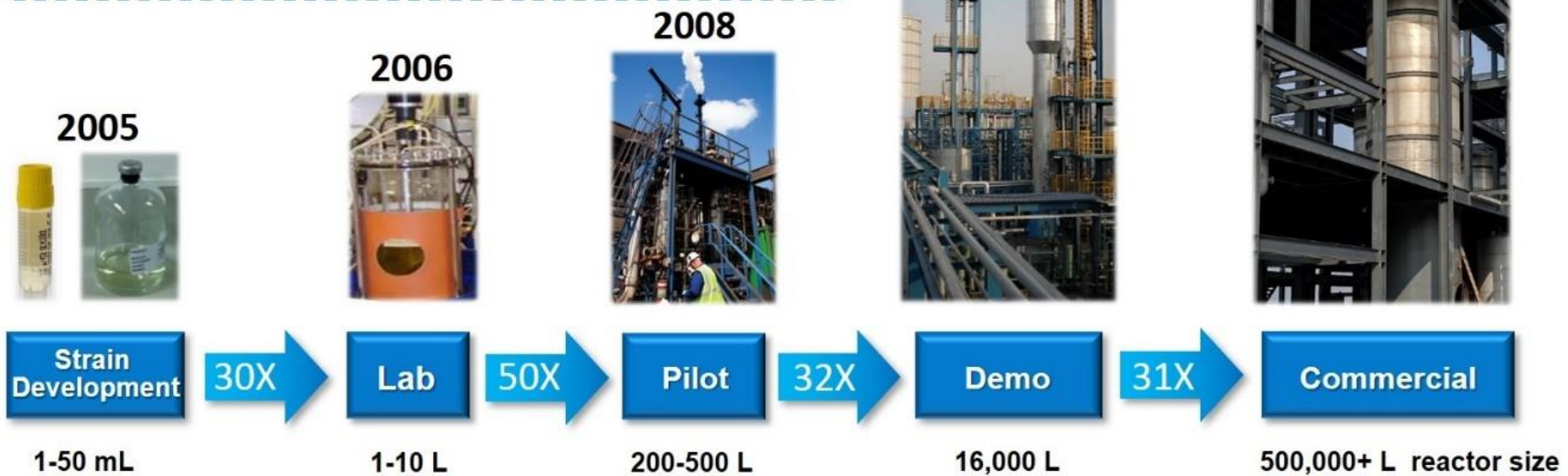
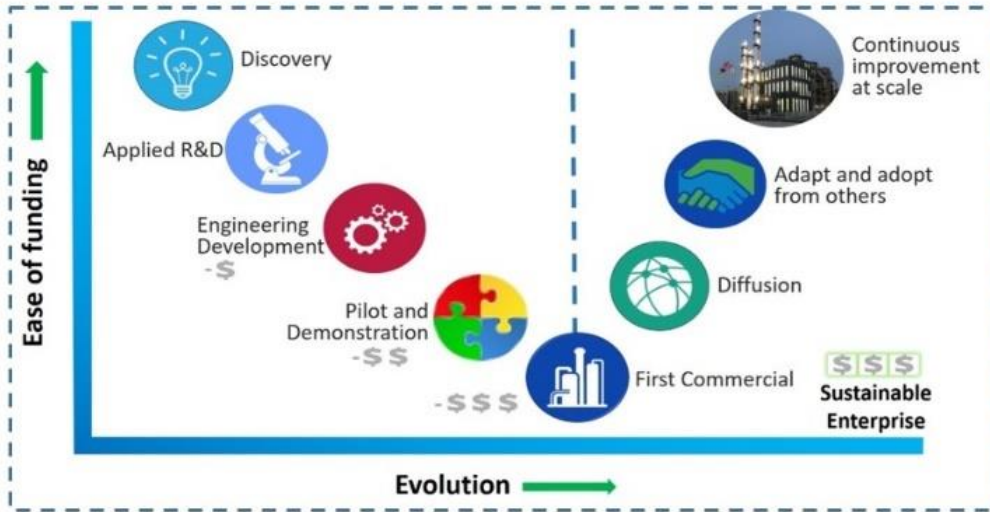
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BEIO Invests in Applied R&D and Large-Scale Demonstration



● Government
 ● Project Recipients and Partners
 ● Banks

From Strain Development to Commercial Operation



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

A BILLION DRY TONS OF SUSTAINABLE BIOMASS

HAS THE POTENTIAL TO PRODUCE

1.1 MILLION Direct Jobs
and keeps about
\$250 BILLION
in the U.S.
(direct contribution
and inflation adjusted)



85 BILLION*
kWh of electricity
to power
6 MILLION
households. Plus
1050 TRILLION BTUs
of thermal energy.



50 BILLION
gallons of biofuels
displacing almost
25%
of all transportation
fuels.



50 BILLION POUNDS
of biobased
chemicals and bio-
products, replacing
a significant portion
of the chemical
market.



400 MILLION TONS
of CO₂e
reductions
every year.



STEPS TO BUILDING THE BIOECONOMY

- 1 Accelerate research & technology development
- 2 Develop production, conversion and distribution infrastructure
- 3 Deploy technology
- 4 Create markets and delivery systems

Projections based on:

- 2016 Billion Ton Study Report (Forthcoming)
- EIA 2015 AEO
- 2015 USDA Long-Term Forecast
- Various data sources

* Includes 27 billion kWh and 90 TBtu from livestock anaerobic digestion