U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

8th Carinata Biomaterials Summit

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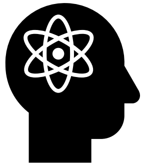
DOE-EERE Overall Decarbonization Strategy

Accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to a carbon pollution-free electricity sector by 2035 and a economy by no later than 2050, creating good-paying jobs with the free and fair chance to join a union, and ensuring the clean energy economy benefits all Americans, especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution.

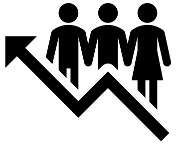
EERE Mission

Keys to Ensure the Greatest Impact

Environmental Justice and Equity



Diversity in STEM



Workforce Development

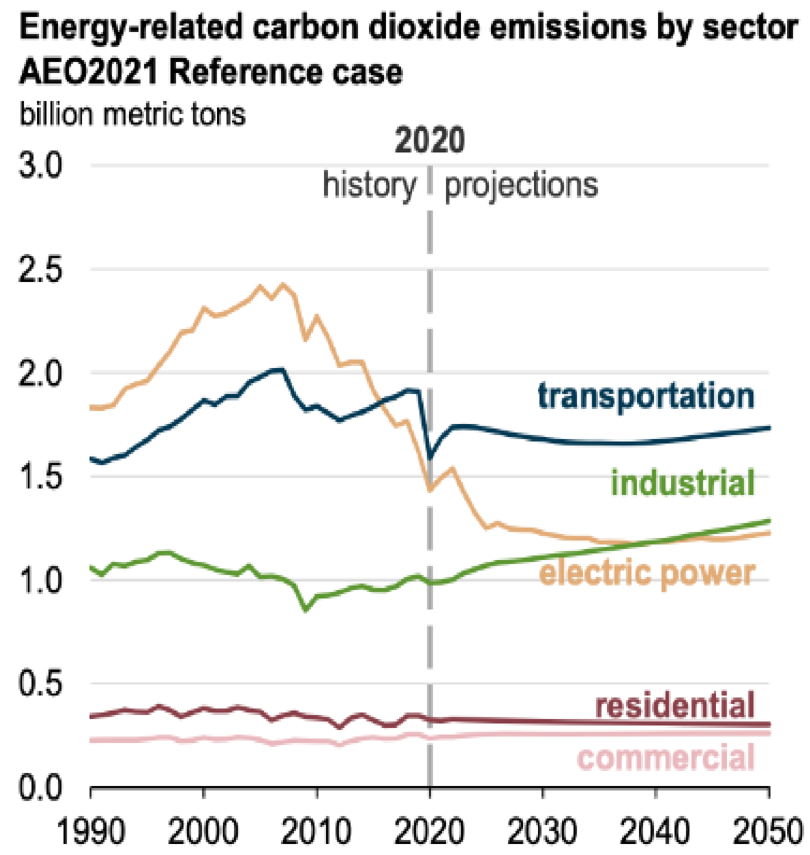
State and Local Partnerships

EERE Program Priorities

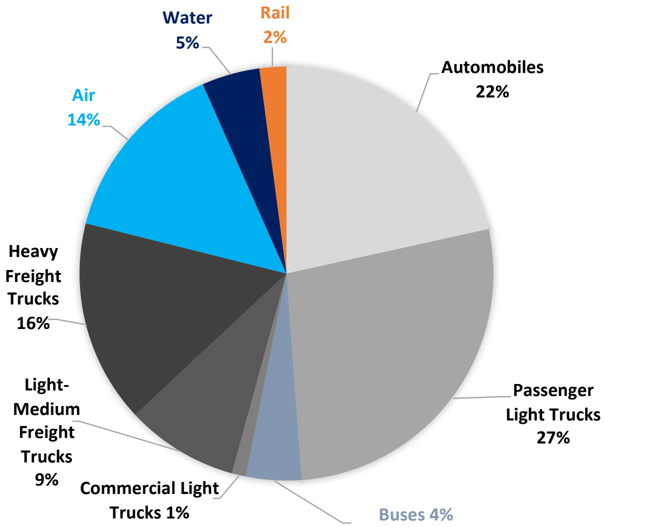
- Decarbonizing the electricity sector
- Decarbonizing transportation across all modes
- Decarbonizing energy-intensive industries
- Reduce the carbon footprint of buildings
- Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water

Context For Transportation Decarbonization

- **Largest source of economy-wide CO_2 emissions**: net-zero by 2050 requires dramatic improvement from transportation
- 50% of **energy expenditures** and **a local pollution issue**
- The magnitude of industrial change and direct consumer touch points with transportation require **market-pull solutions**
- Must **support demand for growth in mobility options**
- **100% clean electricity and dramatic technology cost** reductions enable deep transportation decarbonization
- Achieving 2050 goal requires success in the market by 2035 which **requires direction in 2021**
- Significant implications for global competitiveness, trade, and **domestic jobs**



The Real Challenge: Low-Carbon Fuel for Large Vehicles



Demand for mobility in the US is **projected to grow** with population and economy:

- Light-duty vehicles: +20% by 2050
- Trucking: **+40%** by 2050
- Aviation: **+70%** by 2050

Energy use for **"hard-to-electrify"** heavy vehicles is projected to reach ~70 B gallon in 2050:

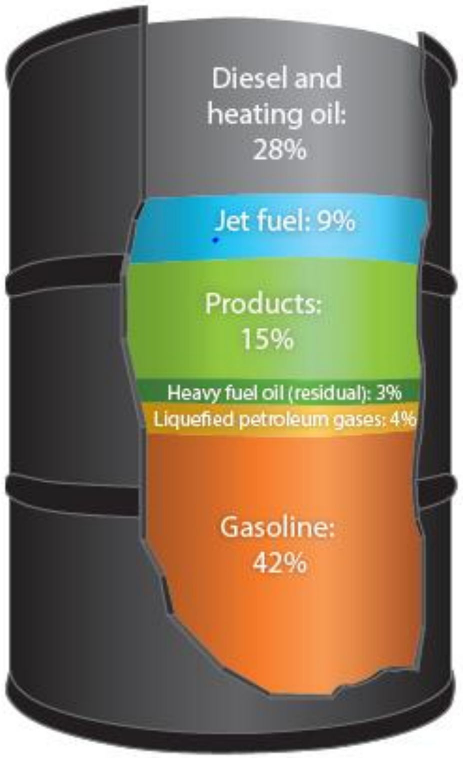
- Aviation: 36 B Gal
- Maritime/Rail: 11 B Gal
- Long-haul trucks: 21 B Gal

Biomass-Derived Chemicals

- Broadens opportunity to expand biomass markets.
- Allows us to address fuel and products (i.e. economics of the whole barrel)

<u>Inputs</u>:

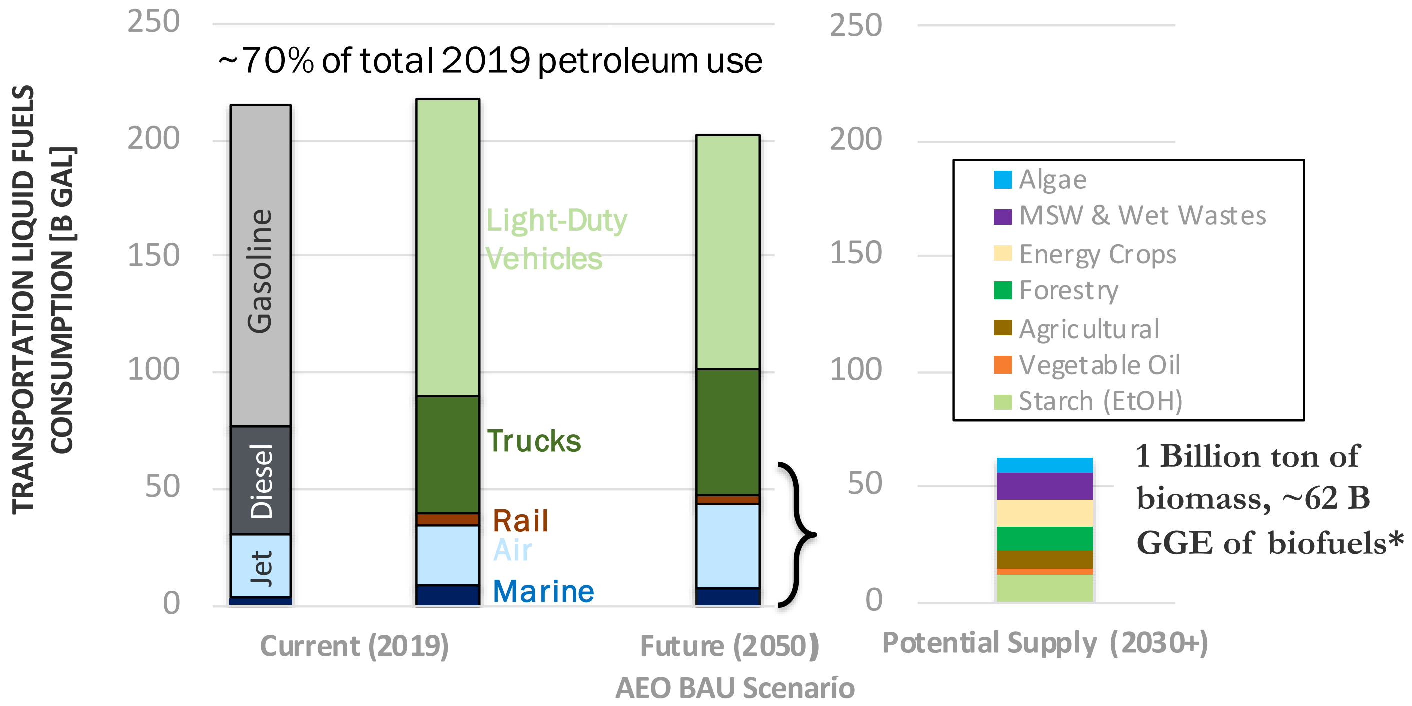
- Cellulosic based crops & ag. residue
- Oil based crops
- Algae
- Bio-solids
- MSW
- Waste gas (CO, C02)



<u>End Products</u>:

- Fuels
  - Aviation
  - Marine & Diesel
  - Gasoline
- Chemical Products: (15% Volume 46% Profit)

New, Growing Markets for Biomass will be Critical



Role of cover crops are not well defined in the Billion Ton Study: Carinata, Camelina, and Penny Crest

NEEDS:

- Data on harvest, collection, storage, transport, and preprocessing
- Incorporate data into models to develop supply curves, evaluate economic competitiveness and environmental benefits

- **Current markets for biomass include starch-ethanol, biodiesel, renewable diesel and sustainable aviation fuels and some chemicals**
- **Focus biomass where it can make the biggest impact in terms of CO2 reduction creates opportunity for significant new markets for biomass**
- **Biomass role in decarbonizing the economy:**
  - Fully **supply future Aviation/ Maritime/Rail** (requires 75% of all feedstocks)
  - Only potential renewable liquid carbon source available to the **chemicals industry.**
  - **Increase CO2 in the soil** while helping farmers maximize profits on marginal lands, by providing valuable feedstocks for bioenergy production

Fuel and Chemical GHG impacts

Biofpr Biofuels Bioproducts & Biorefining — SCI where science meets business

Modeling and Analysis | Open Access

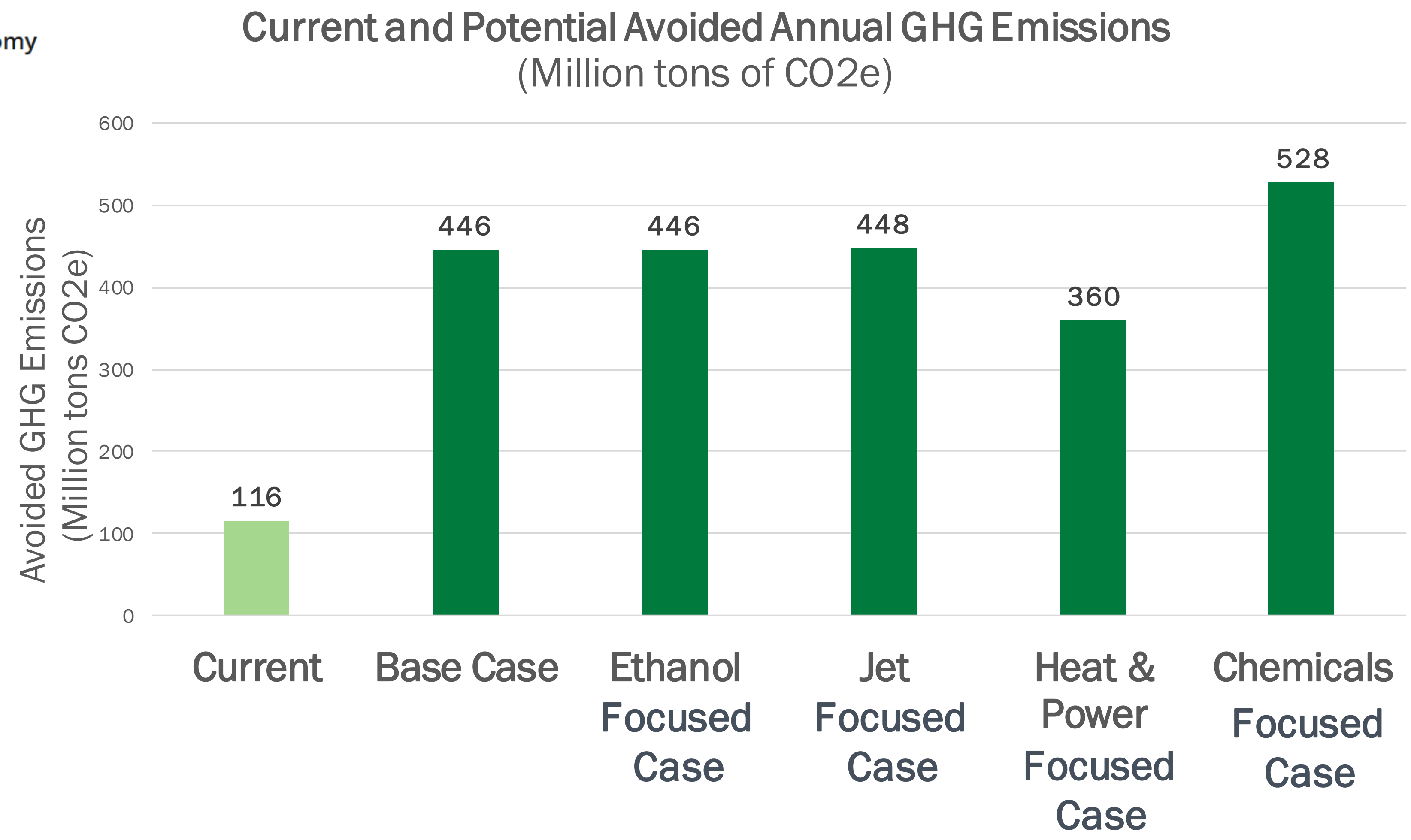
An assessment of the potential products and economic and environmental impacts resulting from a billion ton bioeconomy

Jonathan N. Rogers, Bryce Stokes, Jennifer Dunn, Hao Cai, May Wu, Zia Haq, Harry Baumes

First published: 21 November 2016 | https://doi.org/10.1002/bbb.1728 | Citations: 32

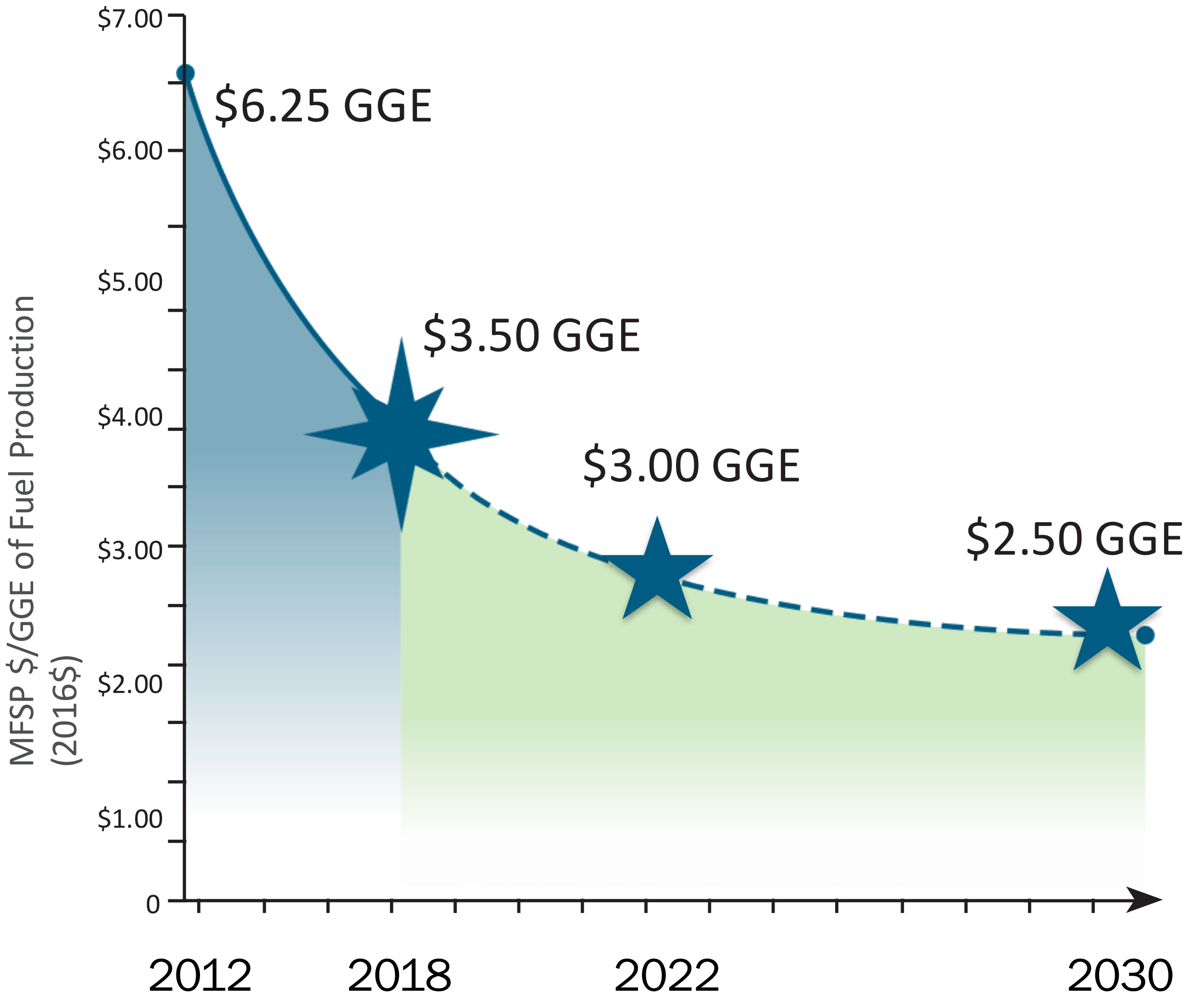
The billion tons of sustainable biomass available in the US can go to a variety of products with large GHG benefits in all scenarios

- Billion Ton Scenarios were "optimized" for different fuels/products (e.g., ethanol, jet)
- All scenarios includes a range of liquid transportation fuels, heat & power, chemicals, wood pellets, etc.
- All scenarios suggest significant GHG benefits vs. current biomass utilization.



Biofuels, Bioproducts and Biorefining, Volume: 11, Issue: 1, Pages: 110-128, First published: 21 November 2016, DOI: (10.1002/bbb.1728)

EERE SAF Goals and Impact



MFSP = minimum fuel selling price

GOALS

R&D: Cost Reduction with Maximum CO_2 Reduction

2022 $3.00/GGE 60% greenhouse gas (GHG) reduction
2030 $2.50/GGE 70% GHG reduction

Demonstration: Increase Commercial Supply of SAF

2030 Demonstrate as many as 5 feedstock/technology pathways at engineering scale to reduce risk for commercial build out.
Equip traditional biofuels industry to transition to SAF with GHG reductions of >70%.

2040 Aggressive industrial build-out resulting in >17B gal SAF in market.

2050 Aggressive industrial build-out resulting in 35B gal SAF in market – 100% projected aviation needs.

LONG-TERM IMPACTS

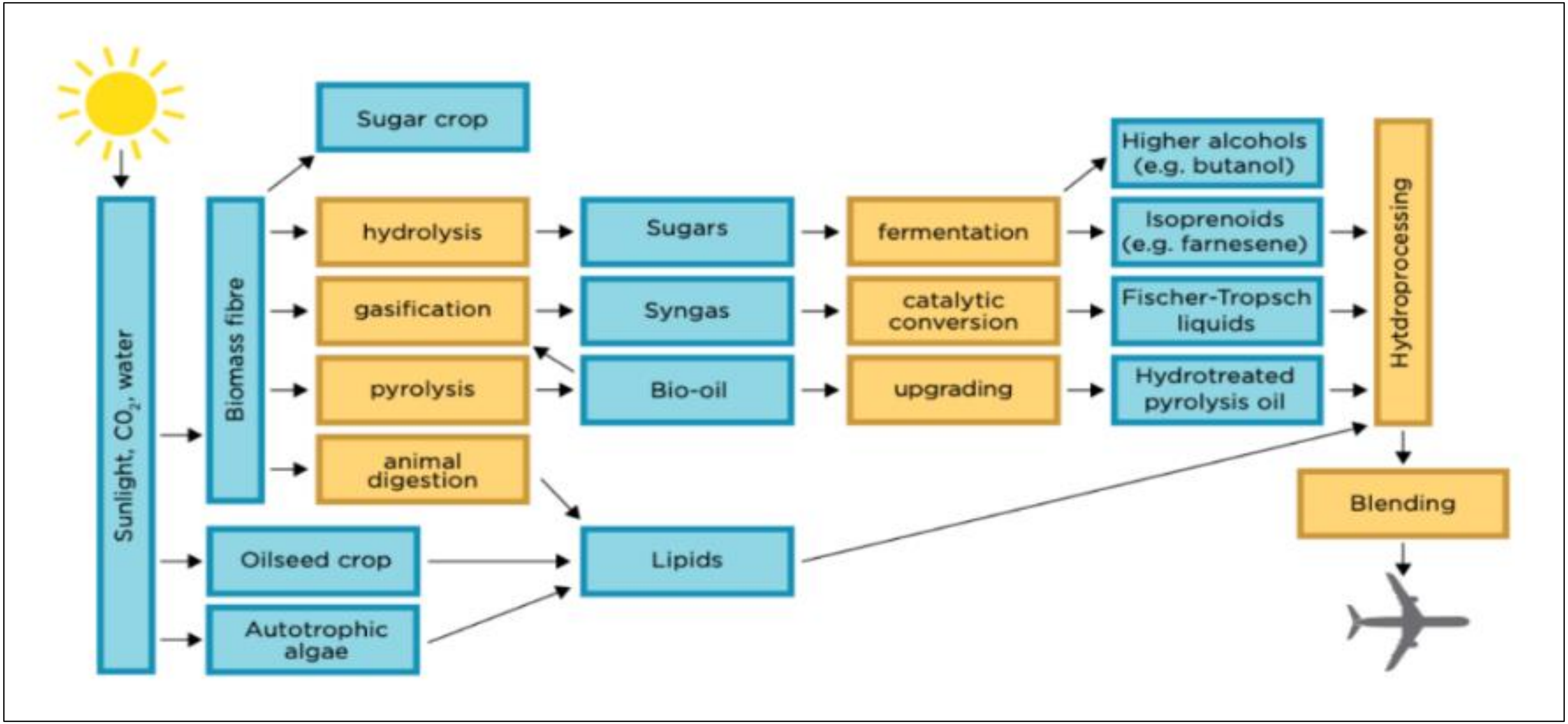
60B gal renewable hydrocarbon fuels
40B pounds of renewable chemicals
>450 million tons CO_2 reduced annually
1 million direct jobs

Billion Tons of Sustainable Biomass For SAF

Feedstock	Ex Conversion Processes	Feedstock Input million dry tons/yr
Seed Oils	FAME/HEFA	9
Corn grain	Fermentation to EtOH/Alcohol to Jet	148
Fats, oils, greases	HEFA	7
Forestry resources & woody wastes	Gasification with Fischer Tropsch synthesis	133
Woody energy crops		50
MSW		55
Agricultural residues	Isobutanol - Alcohol to Jet	149
Herbaceous energy crops		190
Algae	Combined Algae Processing	24
Algae	Hydrothermal Liquefaction	24
Wet Wastes		78
Currently used biomass - non-biofuel		238
TOTALS		1,103

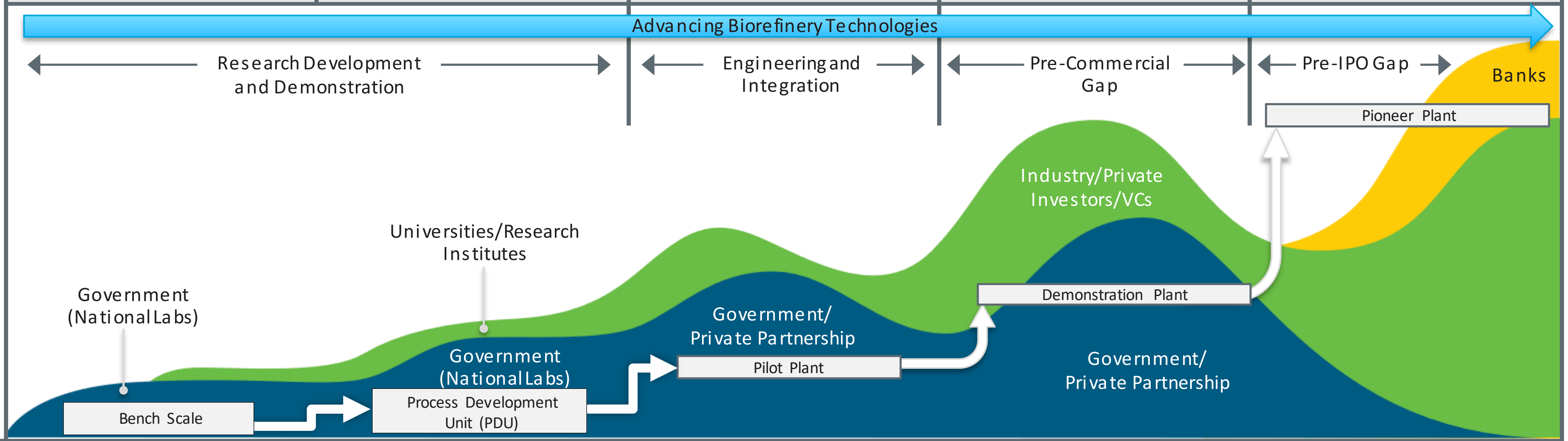
- 1 billion ton biomass (BtB) = >60 billion gal of fuel
  - >450 MMT CO_{2e} reduction/yr
- Sustainability factors – life cycle GHG emissions, fossil energy consumption, land allocation and water consumption.
- Land Use change
  - @$40/dt 5.6 M/230 M acres will shift from commodity crops to energy crops and
  - @$60/dt 30M/230M acres crop land and 49M/460M acres pasture will shift
    - Differences made up in increased crop productivity (2% annually) and managed-intensive grazing
- >10 different technologies will be necessary to transform diverse biomass into SAF.
- Technologies are at different maturity levels, with some ready for demo and some with substantial remaining R&D.

EERE has Developed Multiple SAF Pathways



Demo-Scale Projects Key to De-risk and Accelerate Commercialization

	R&D	Pre-Pilot	Pilot	Demonstration	Commercial
	TRL 2-3	TRL 4-5	TRL 6	TRL 7	TRL 8-9



	R&D	Pre-Pilot	Pilot	Demonstration	Commercial
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

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