Sustainable Aviation Fuel Grand Challenge

DOE's Progress Toward Meeting the Goals of the SAF Grand Challenge

Presenters

Dr. Valerie Reed - Zia Haq – Dr. Art Wiselogel – Dr. Ian Rowe - Dr. Mark Shmorhun - Sheila Dillard

February 22, 2023

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

BIOENERGY TECHNOLOGIES OFFICE

Sustainable Aviation Fuel Grand Challenge

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Agenda

1. Valerie Sarisky-Reed, SAF Grand Challenge Overview
2. Zia Haq, SAF Grand Challenge Roadmap
3. BETO Support and Alignment with the SAF GC Roadmap
   A. Art Wiselogel, Feedstock Innovation
   B. Ian Rowe, Conversion Innovation
   C. Mark Shmorhun, Building Regional SAF Supply Chains
   D. Zia Haq, Enabling End Use
   E. Zia Haq, Policy and Valuation Analysis
   F. Sheila Dillard, Communicating Progress and Building Support
4. Q&A

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About the Bioenergy Communicators (BioComms) Working Group

Sponsor:

- U.S. Department of Energy (DOE)
- Office of Energy Efficiency and Renewable Energy (EERE)
- Bioenergy Technologies Office (BETO)

BETO & DOE National Laboratory Members:

- Bioenergy communicators, laboratory relationship managers, BETO tech team, and education and workforce development professionals

Purpose:

- Communications strategy for BETO-funded bioenergy research and development

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Today's Presenters

Dr. Valerie Reed

Zia Haq

Dr. Art Wiselogel

Dr. Ian Rowe

Dr. Mark Shmorhun

Sheila Dillard

Sustainable Aviation Fuel
Grand Challenge

SAF Grand Challenge

Overview

Dr. Valerie Sarisky-Reed

SAF Grand Challenge Timeline and Goals

Sep 2021
White House Announcement

Nov 2021
U.S. Aviation Climate Action Plan

Sep 2022
Grand Challenge Roadmap

Jan 2023
Transportation Decarbonization Plan

2030
3 BGY Goal

2050
35 BGY Goal

Sustainable Aviation Fuel Grand Challenge

What We Need To Be Successful

- **Create an environment where producers choose to produce and sell sustainable aviation fuel (SAF)**
  - Legislative action to reduce cost and risk – Inflation Reduction Act
- **A coordinated approach to federal actions that derisks** technology, supply chains, and markets, and reduces barriers
  - Actions that support near-term production
  - Ongoing innovation to support future production
  - Data collection and analysis to support markets for SAF through strong policies
- **Industry to build and purchase SAF supply**

SAF Grand Challenge Roadmap

Sustainable Aviation Fuel Grand Challenge

Inflation Reduction Act - Provisions for SAF

**Signed into law by President Biden on 08/16/2022*

SAF Tax Credits

- Section 13203 SAF Credit
- SAF must achieve >50% greenhouse gas (GHG) reduction to be eligible
- Tax credit starts at $1.25/gallon of neat SAF and increases by $0.01/gal for each percentage point improvement in GHG performance up to $1.75/gal
- Credits can be “stacked” with Renewable Identification Numbers and state Low Carbon Fuel Standard credits
- Section 13704 Clean Fuel Production Credit

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Bioenergy Technologies Office Is Driving Forward SAF R&D

Production and Harvesting

Feedstock Technologies

- Lower costs
- Improve quality
- Increase types of feedstock intermediates available for conversion.

Advanced Algal Systems

- Increase algae productivity
- Algal strain improvement and efficient cultivation.

Conversion and Refining

Conversion Technologies

- Reduce costs of deconstructing feedstock into intermediate products
- Upgrade intermediates into liquid biofuels (e.g., SAF), bioproducts, and biopower

Distribution and End Use

Systems Development and Integration

- Systems research to combine tech, operations, subsystems developed by R&D programs into integrated processes.
- Integrated processes tested (pre-pilot to demo scale) to identify R&D needs, readiness for scale-up and commercialization.

Crosscutting

Data, Modeling, and Analysis

- Track technology progress and identify opportunities and challenges related to economic/environmental impact of advanced bioenergy systems.

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SAF GC Roadmap

Overview

Zia Haq

SAF Grand Challenge Roadmap

U.S. Departments of Energy, Transportation, and Agriculture launched the SAF Grand Challenge through a Memorandum of Understanding (MOU).

Goals include:

- Achieving a minimum of a 50% reduction in life cycle greenhouse gas emissions compared to conventional fuel.
- Supplying sufficient SAF to meet 100% of aviation fuel demand by 2050.

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Roadmap Purpose

- A multi-agency plan of federal agency action
- Supports stakeholders to build the SAF supply
- Derisk technology, supply chains and markets, and reduce barriers by:
  - Leveraging existing government research, development, demonstration, and deployment support
  - Accelerating new research, development, demonstration, and deployment support
  - Supporting policy framework

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Roadmap Implementation – Next Steps

- Federal agency involvement
  - Map existing and planned activities aligned with roadmap
  - Identify research, development, demonstration, and deployment gaps and funding needs
- Stakeholder engagement
  - Obtain external stakeholder input on federal activity plans
  - Provide recommendations on research focus areas
  - Identify/map industry supported/funded efforts aligned with roadmap
  - Identify opportunities for public-private partnerships to implement roadmap actions (e.g., working groups/technical teams)
- Communications
  - Develop and launch a SAF Grand Challenge website
  - Planning for an FY23 Roadmap Annual Progress Report

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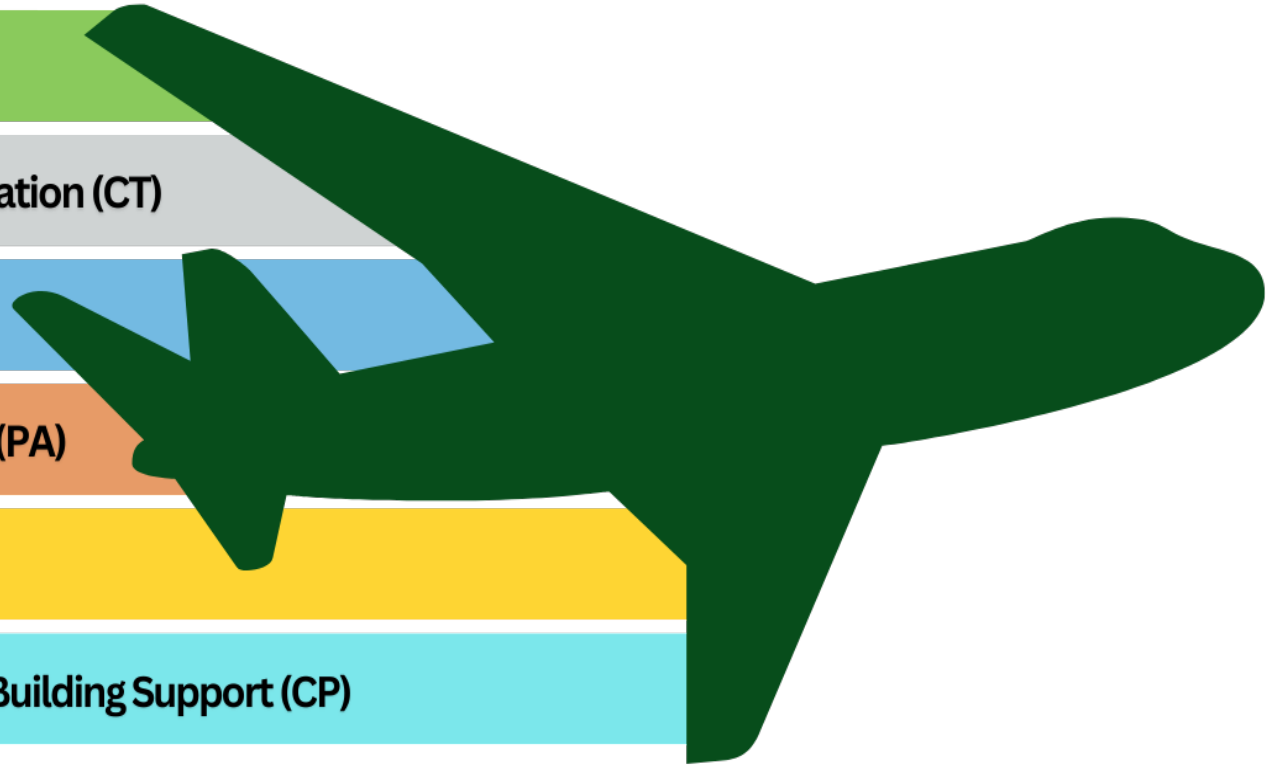
Six Action Areas

1. Feedstock Innovation (FI)
2. Conversion Technology Innovation (CT)
3. Building Supply Chains (SC)
4. Policy and Valuation Analysis (PA)
5. Enabling End Use (EU)
6. Communicating Progress and Building Support (CP)



26
Workstreams

139
Activities that Impact 2030 and 2050 Goals

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SAF GC Roadmap

Feedstock Innovation

Dr. Art Wiselogel

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BIOENERGY TECHNOLOGIES OFFICE

Action Area: Feedstock Innovation (FI)

Support and conduct R&D on sustainable feedstock supply system innovations across the range of SAF-relevant feedstocks and identify optimization to reduce cost, reduce technology uncertainty and risk, increase yield and sustainability, and optimize SAF precursors.

Feedstock Innovation Workstreams

FI.1 Understand resource markets and availability across all SAF feedstocks

FI.2 Maximize sustainable lipid supply for 2030

FI.3 Increase production of biomass resources and collection of wastes and residues

FI.4 Improve feedstock supply logistics (e.g., harvest/collection, transport, storage, preprocessing)

FI.5 Increase reliability of feedstock handling systems

FI.6 Improve sustainability of biomass and waste supply systems

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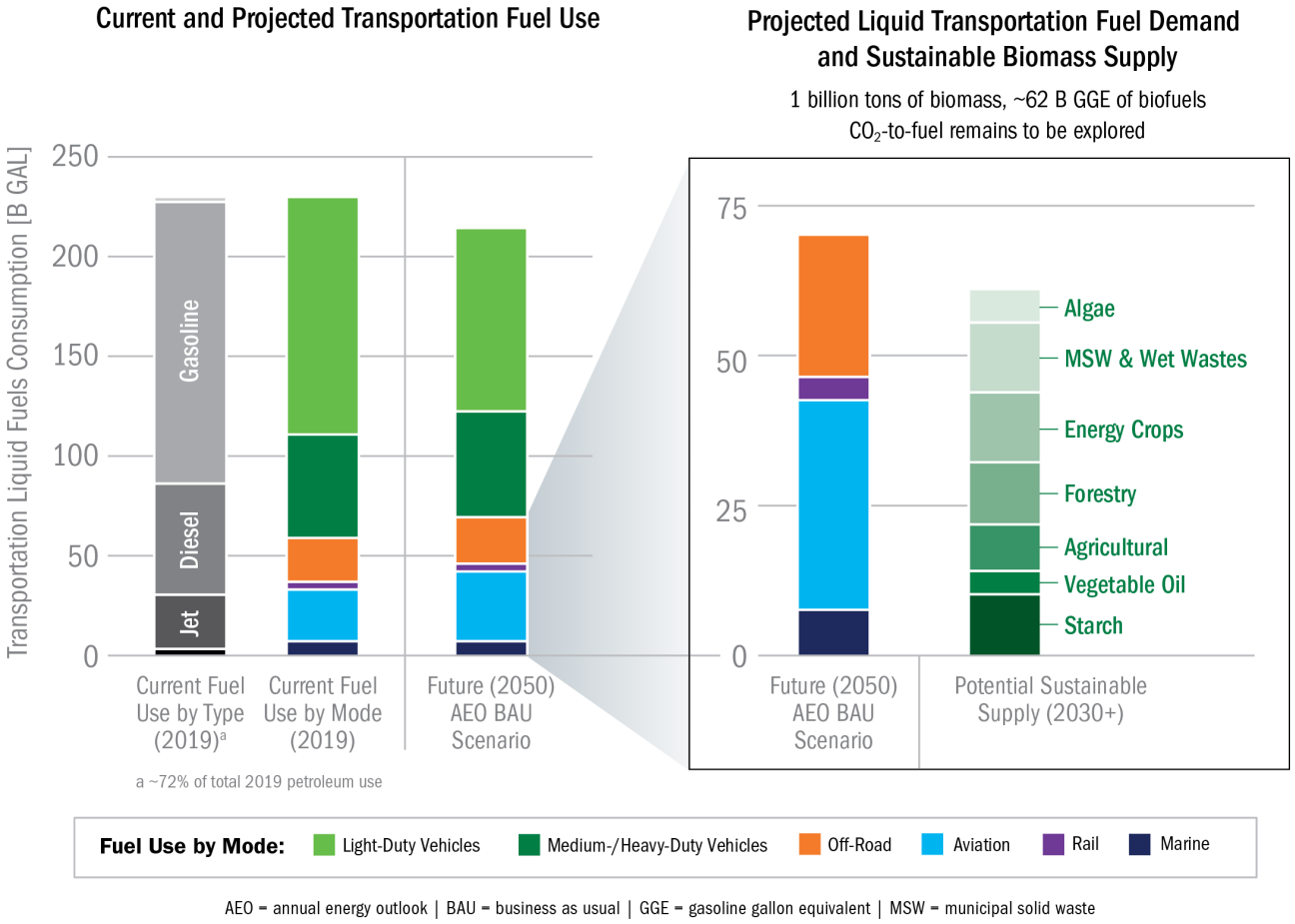
Feedstock Needs for SAF

Diverse Biomass & Waste Resources

- ~645 million tons of biomass/waste needed annually to meet SAF production
- DOE estimates over 1 billion tons of feedstocks can eventually be sustainably produced in the United States each year
- No single resource type is sufficient
- To mobilize all the available biomass resources will take R&D funding for technology development by DOE, the U.S. Environmental Protection Agency, and the U.S. Department of Agriculture



AEO = annual energy outlook | BAU = business as usual | GGE = gasoline gallon equivalent | MSW = municipal solid waste

Multi-Agency Stakeholder Plan To Build SAF Feedstock Supply

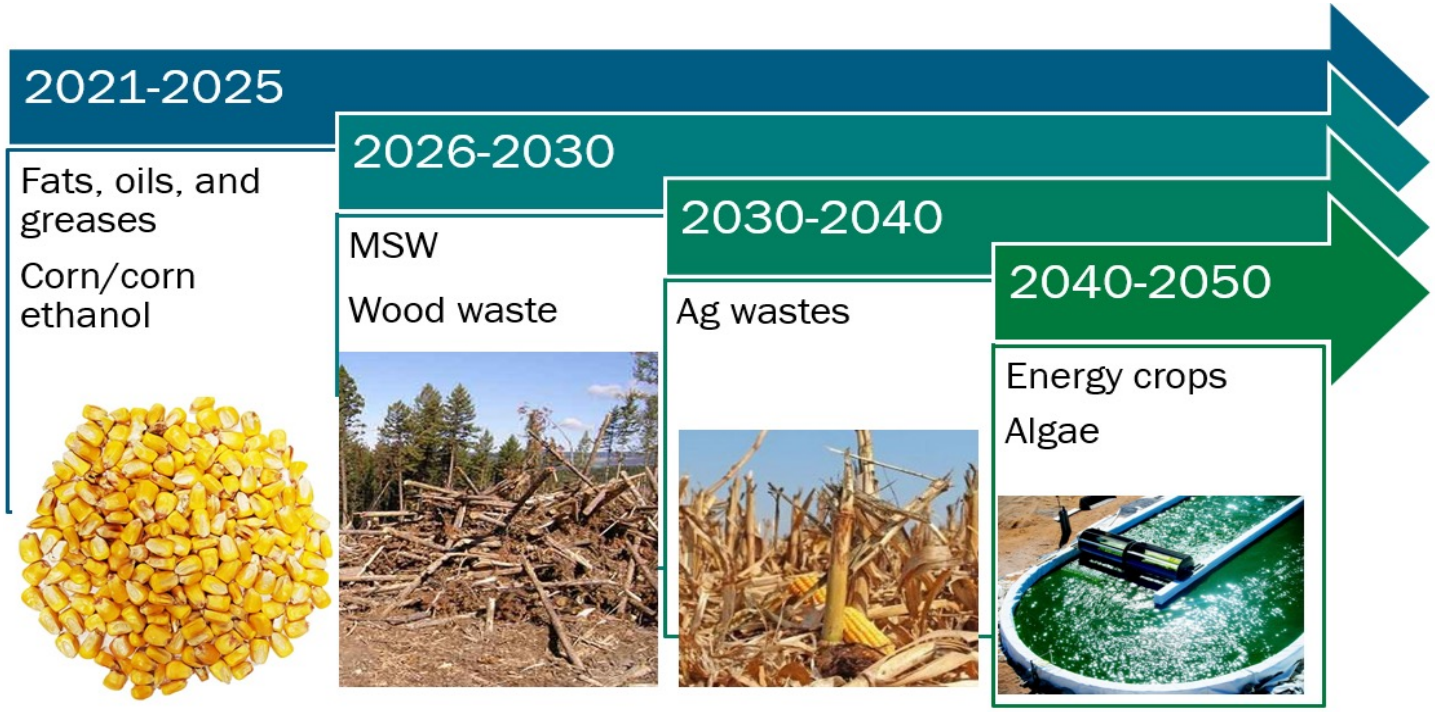
DOE funds R&D to tackle technology and supply-chain

Near-term Resources

- Fats, oils, and greases that can be used in current hydro-processing technology
- Starches and sugars that can be used in alcohol to jet fuel Technology

Long-term Resources

- Biological waste, crop residues, and forest residues
- Purpose grown crops like algae and switchgrass



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Multi-Agency Stakeholder Plan To Build SAF Feedstock Supply

- Feedstock logistics projects and state of the technology studies to develop advance supply chains
- Feedstock-Conversion Interface Consortium to develop pre-processing technologies for agriculture and forest residues, and municipal solid waste
- Waste sorting and artificial intelligence projects to improve resource purity

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Multi-Agency Stakeholder Plan To Build SAF Feedstock Supply

- Analysis and understanding of carbon intensity of biomass resources
- Regional Biomass Partnership to understand the production of purpose-grown energy crops
- Large-scale algae cultivation studies focused on greater productivity, improved carbon dioxide (CO_2) utilization efficiency and enhanced biomass quality

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SAF GC Roadmap

Conversion Innovation

Dr. Ian Rowe

Action Area: Conversion Technology Innovation (CT)

Support and conduct R&D, through pilot scale, on unit operations (and integration thereof) from the receipt of biomass at the refinery gate through to finished fuel for technology improvements/carbon intensity reductions. The effort includes processes that are already commercial, such as hydroprocessed esters and fatty acids (HEFA), or nearing commercialization (alcohol-to-jet) and considers work on processes that will be ready for commercialization beyond 2030 but need to be developed now.

Conversion Technologies Workstreams

CT.1 Decarbonize, diversify, and scale current fermentation-based fuel industry

CT.2 Develop options to increase production and reduce carbon intensity of existing ASTM-qualified pathways

CT.3 Develop biointermediates and pathways for compatibility with existing capital assets

CT.4 Reduce risk during scale-up and operations

CT.5 Develop innovative unit operations and pathways

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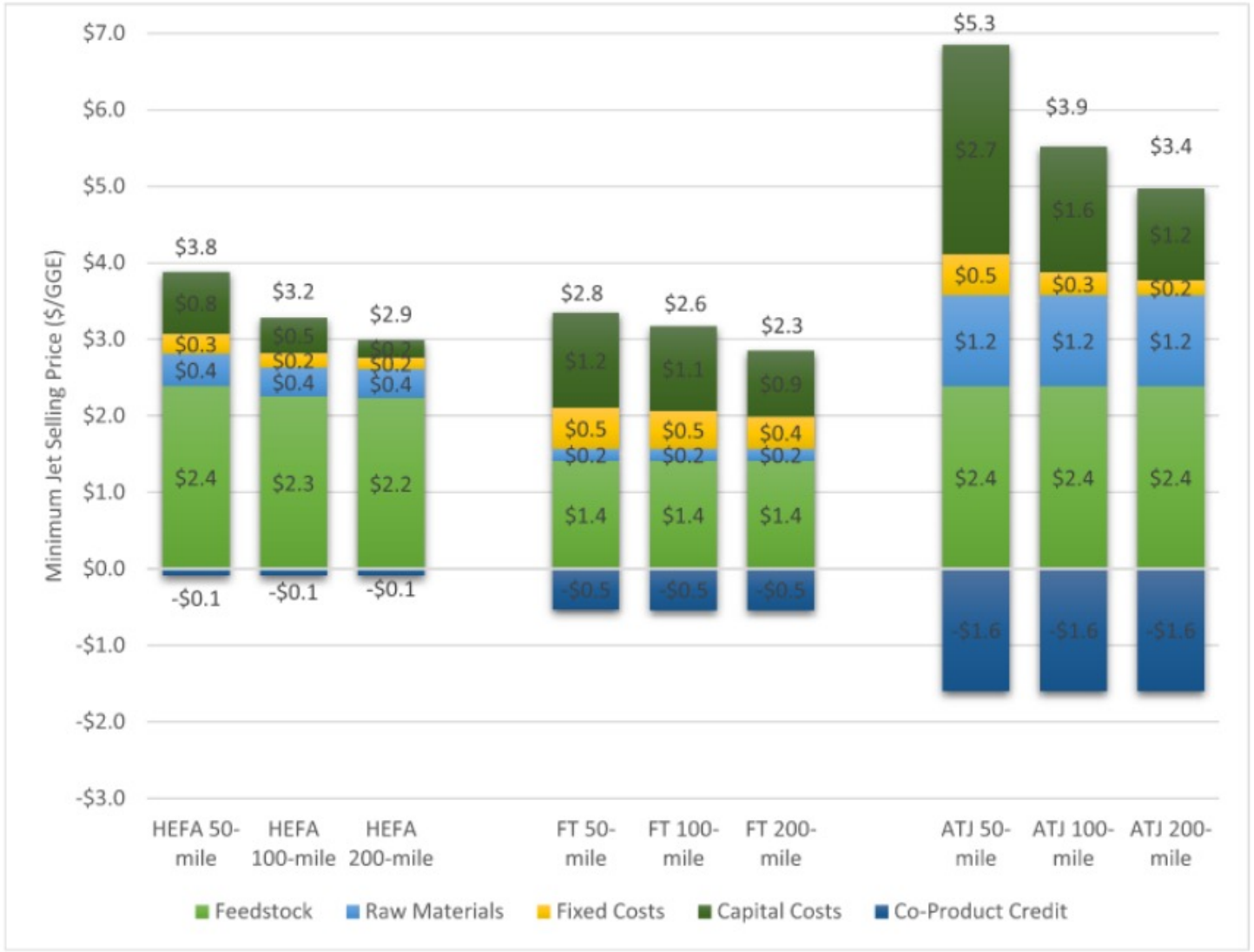
Investing in Research and Development To Commercialize Near-Term Options



Currently conducting applied R&D to enable a wide number of near-term SAF routes, including:

- HEFA
- Fischer-Tropsch
- Alcohol-to-jet

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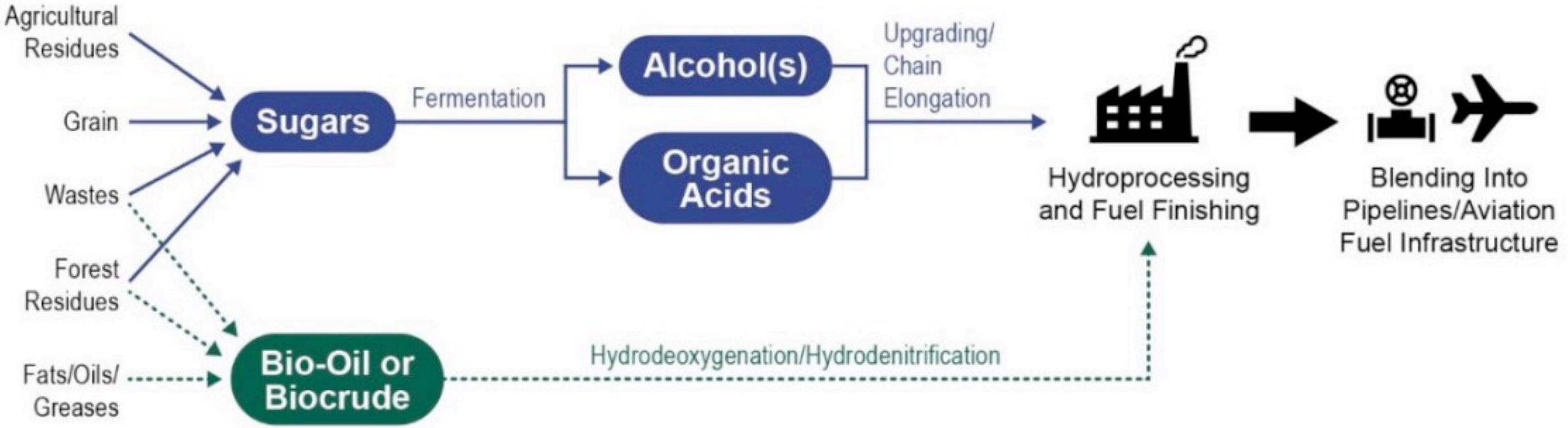
Enabling an Array of Routes and Leveraging the Right Capabilities



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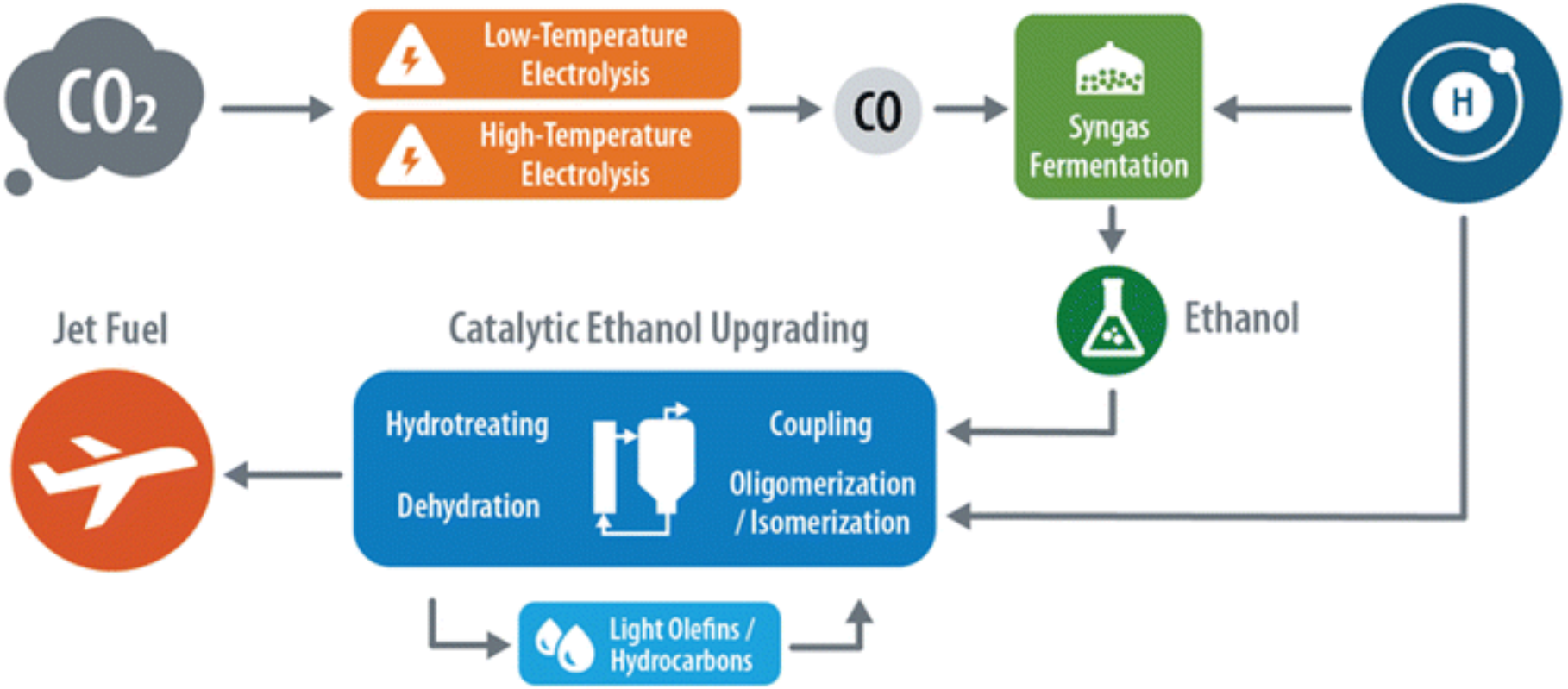
Investments To Enable Emerging SAF Technologies for 2050 Deployment



Lower TRL technologies, such as CO_2 conversion, can leverage technologies that are piloting and deploying today

Grim et al. 2022. "Electrifying the Production of Sustainable Aviation Fuel: The Risks, Economics, and Environmental Benefits of Emerging Pathways Including CO_2." *Energy & Environmental Science*. https://doi.org/10.1039/D2EE02439J.

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SAF GC Roadmap

Building Regional SAF Supply Chains

Dr. Mark Shmorhun

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Action Area: Building Supply Chains (SC)

Support SAF production expansion through supply chains, ensuring R&D transitions from pilot to large scale and field validation and demonstration projects, validating supply chain logistics, enabling public-private partnerships, supporting development of bankable business models, and collaborating with regional, state, and local stakeholders.

Supply Chain Workstreams

SC.1 Build and support regional stakeholder coalitions through outreach, extension, and education

SC.2 Model SAF supply chains

SC.3 Demonstration of SAF supply chains

SC.4 Invest in SAF production infrastructure to support industry deployment

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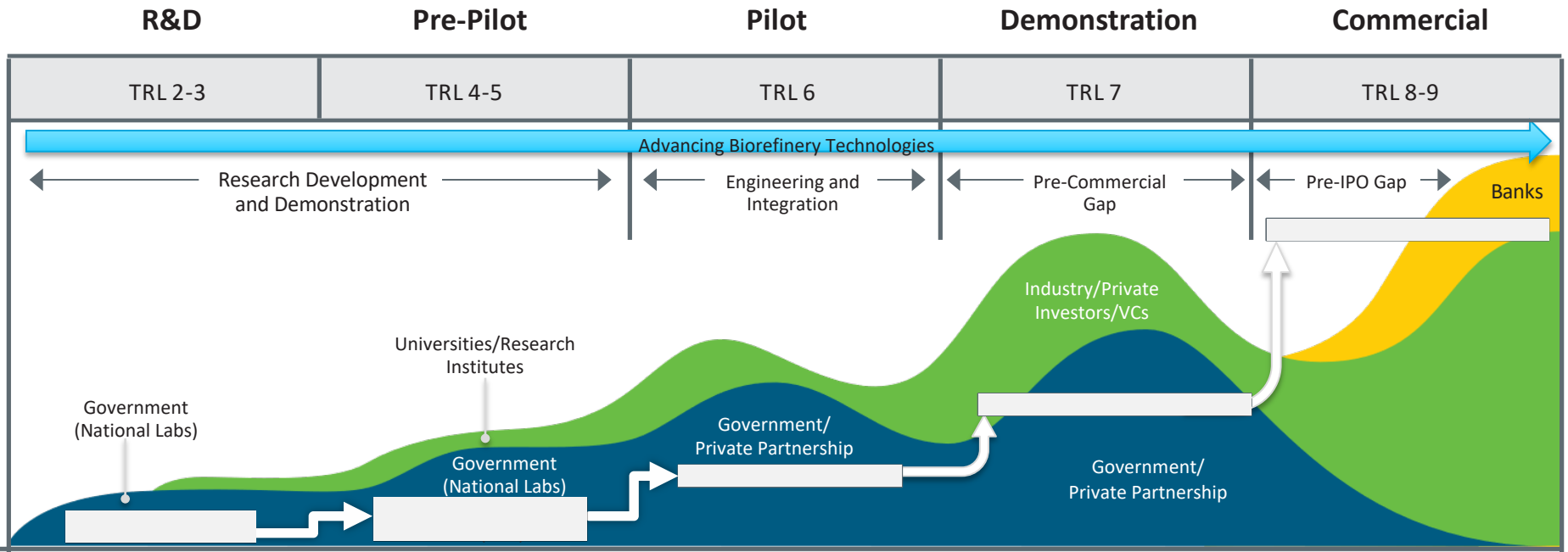
BETO Scale-Up from Lab to Commercial Scale



	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/Bonds/Institutional Investors

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FY23 BETO Pilot and Demonstration Projects

DOE Awards $118 Million to Accelerate Domestic Biofuel Production

- 17 projects will boost production of biofuels for consumer and freight transportation in America, support President Biden's decarbonization and climate agenda
- The selected projects include pre-pilot, pilot, and demonstration projects that will scale-up existing biomass to fuel technologies that will eventually create millions of gallons low-carbon fuel annually.
- The funded projects align with renewable fuels goals in the first-ever U.S. National Blueprint for Transportation Decarbonization, a multi-agency framework for reducing emissions, creating a robust transportation workforce, and securing America's energy independence.
- Award amounts range from $500,000 to $80 million, with most receiving at least $2 million.

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FY23 Pilot and Demonstration Projects

Project	Location	Conversion Technology	Scale	Feedstock	Award
Lanzatech, Inc.	Skokie, IL	Gasification—Gas Fermentation	Pilot	Woody Biomass	Phase 1 Negotiation $1,640,286
Microbio Engineering	San Luis Obispo, CA	Hydrothermal Liquefaction	Pilot	Waste Water Solids	Phase 1 Negotiation $579,673
Alder Fuels, LLC	Southeastern US TBD	Fast Pyrolysis	Demo	Woody Biomass	Phase 1 Negotiation $2,000,000
AVAPCO, LLC	Thomaston, GA	Alcohol-to-Jet	Demo	Woody Biomass	Phase 2 Negotiation $80,000,000

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SAF GC Roadmap

Enabling End Use

Zia Haq

Action Area: Enabling End Use (EU)

Facilitate the end use of SAF by civil and military users by addressing critical barriers, including efficient evaluation of fuel engine performance and safety, advancement of certification and qualification processes, expansion of existing blend limits, and integration of SAF into fuel distribution infrastructure.

Enabling End Use Workstreams

EU.1 Support SAF evaluation, testing, qualification, and specification

EU.2 Enable use of drop-in unblended SAF and SAF blends up to 100%

EU.3 Investigate Jet A fuel derivatives offering performance or producibility advantages

EU.4 Integrate SAF into fuel distribution infrastructure

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DOE SAF End-Use Focus Area

Accelerate SAF adoption to decarbonize the aviation sector by leveraging unique capabilities at DOE labs. Deliver fundamental science, computational tools, and new data for the aviation industry to design next-generation fuels and engines in collaboration with BETO, the Federal Aviation Administration (FAA), NASA, etc.

https://www.nasa.gov/press-release/nasa-dlr-study-finds-sustainable-aviation-fuel-can-reduce-contrails

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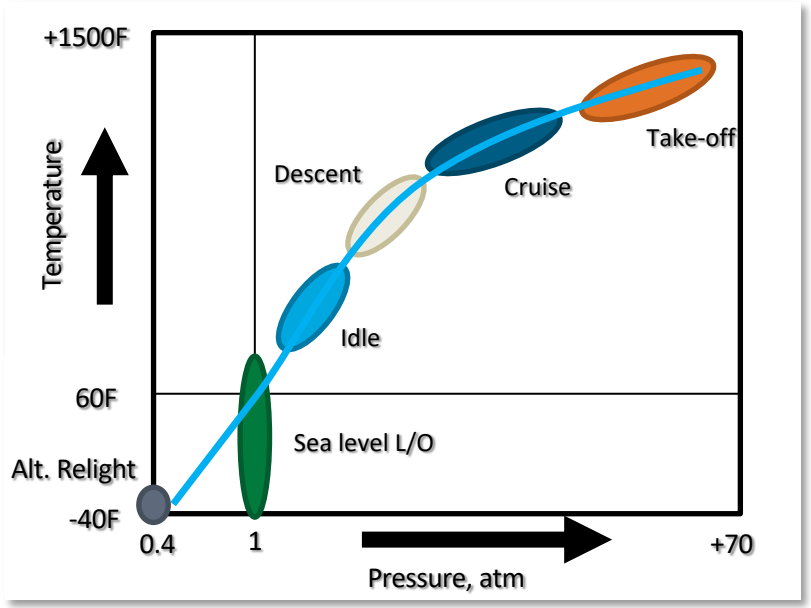
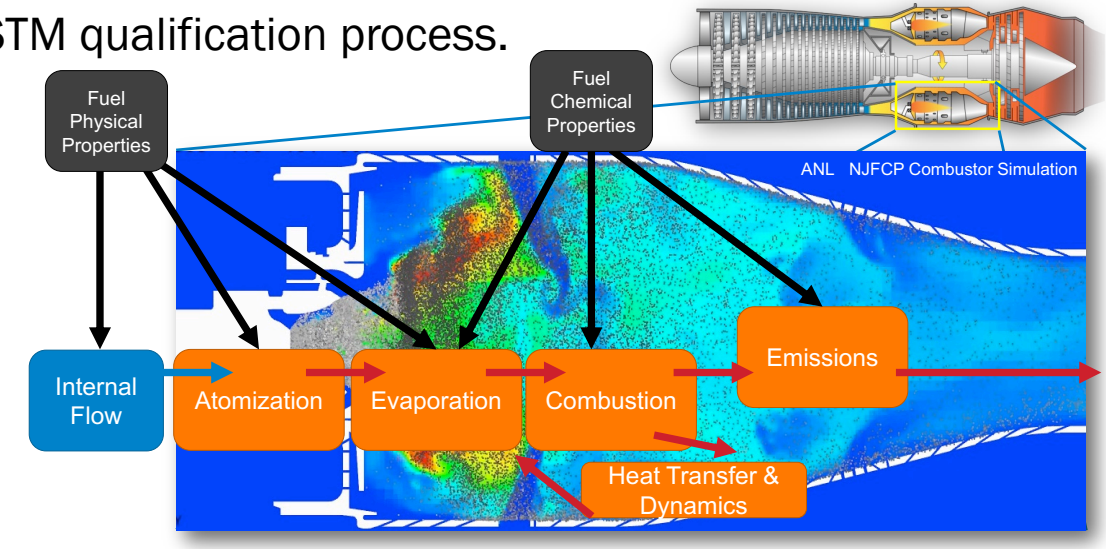
Scope of DOE End Use Research

- ✓ Develop data-knowledge-tools to accelerate SAF adoption for aero-propulsion based on workshop inputs (hosted by Argonne National Laboratory in Feb 2022) provided by industry (GE, Honeywell, Rolls Royce, Raytheon, Pratt, etc.), academia, and other relevant government agencies (FAA, NASA, ARL, AFRL, etc.).
- ✓ Conduct research across broad range of operating conditions (flight map) to understand and predict effects of fuel physical and chemical properties on combustor dynamics.
- ✓ Transfer computational tools, data, fuel property and kinetic mechanisms to industry (via Cooperative Research and Development Agreement, etc.) and enhance existing workflows. Disseminate key findings via high-impact papers and meetings.
- ✓ Accelerate SAF adoption by continuously improving the ASTM qualification process.





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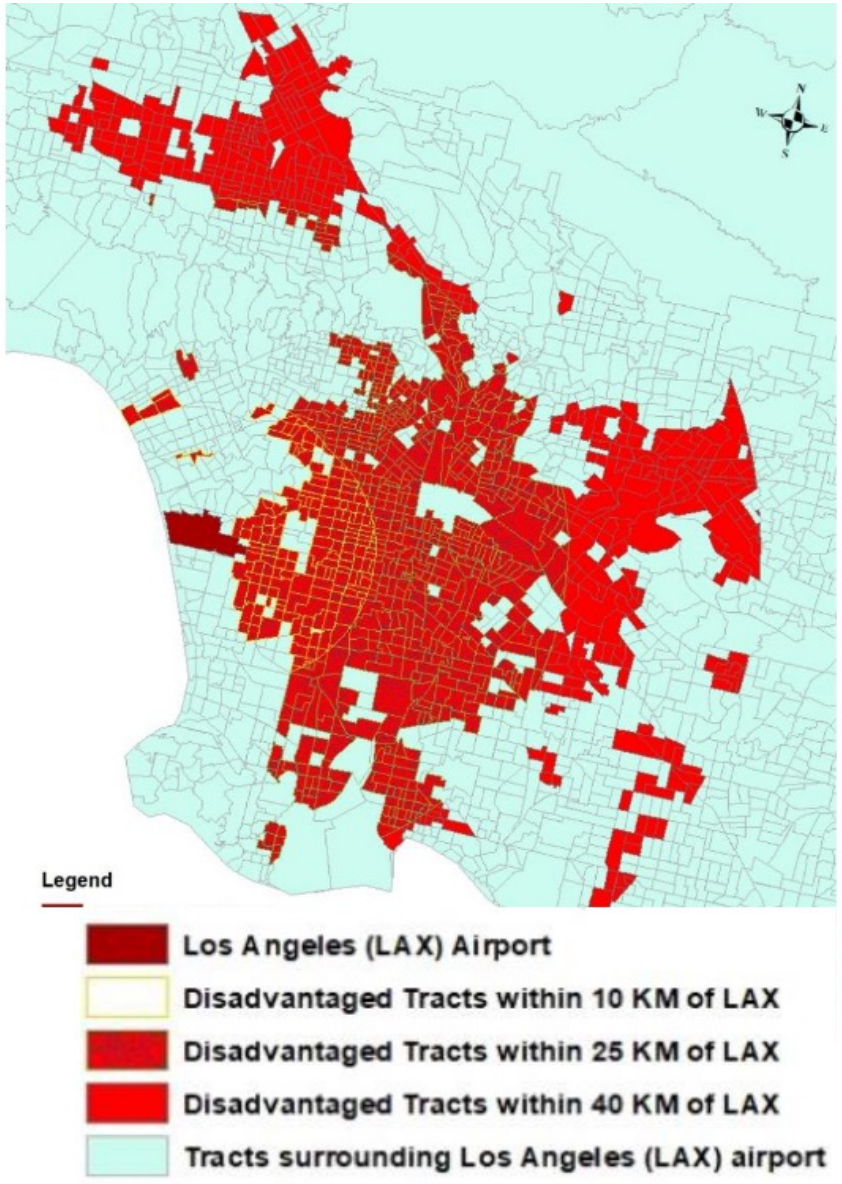
Emissions and Repercussions Research



BETO is sponsoring work at national labs to quantify the health benefits of SAF, particularly those to disadvantaged communities near the nation's airports.

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SAF GC Roadmap

Policy and Valuation Analysis

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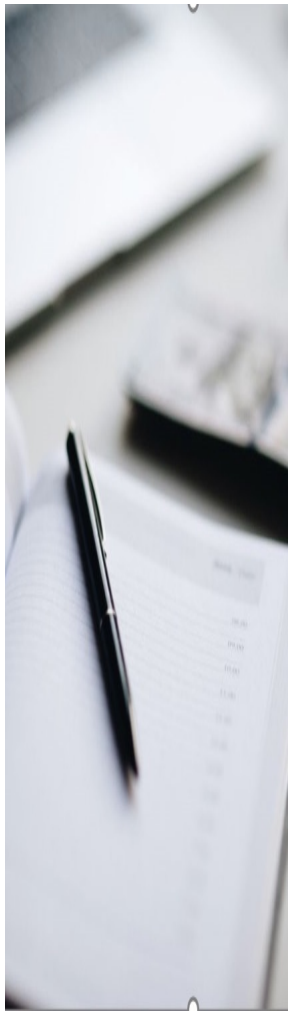
Action Area: Policy & Valuation Analysis (PA)

Provide data, tools, and analysis to support policy decisions and maximize social, economic, and environmental value of SAF including evaluation of existing and new policies.



Policy & Valuation Analysis Workstreams

PA.1 Improved environmental models and data for SAF

PA.2 Conduct techno-economic and production potential analysis

PA.3 Inform SAF policy development

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SAF Life Cycle Analysis Working Group

*(**PA.1** Improved environmental models and data for SAF)*

- From the MOU: "The parties and EPA, along with other relevant agencies, will define and agree on the appropriate science-based methodology for establishing life cycle emissions reductions."
- "Activity PA.1.1: Convene life cycle GHG modeling working group to support needs of the SAF Grand Challenge, in line with the SAF Grand Challenge memorandum of understanding."
- Federal agency working group made up of agency and national labs experts
  - Focus on domestic GHG life cycle assessment (LCA) needs
  - Identify best practices and understand why different methods give different estimates of emissions
  - Examine different approaches being used in LCA models both domestically and internationally
  - Identify commonalities and areas of difference in the models being used
- Support ongoing development of methods and tools to estimate life cycle GHG emissions for use in SAF Grand Challenge activities that require GHG evaluation.

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Techno-Economic Analysis of SAF Fuels

Fig. 7 MJSP for all the pathways with n^{th}-plant assumption.

BETO funds techno-economic analysis (TEA) and feedstock resource assessments of currently commercial technologies to determine how to hit volumetric targets and meet decarbonization goals set out in the roadmap including:

HEFA
Alcohol-to-jet
Fischer-Tropsch

BETO also funds TEA of emerging technologies capable of producing SAF that can be used to hit outyear targets. Examples include:

- Various pathways utilizing algal feedstocks
- Novel catalytic upgrading technologies
- Upgrading of novel sugar-derived intermediates such as 2,3-butanediol

Figure from: Tao, Ling, Jennifer N. Markham, Zia Haq, and Mary J. Biddy. "Techno-Economic Analysis for Upgrading the Biomass-Derived Ethanol-to-Jet Blendstocks." *Green Chemistry* 19, no. 4 (2017): 1082-1101.

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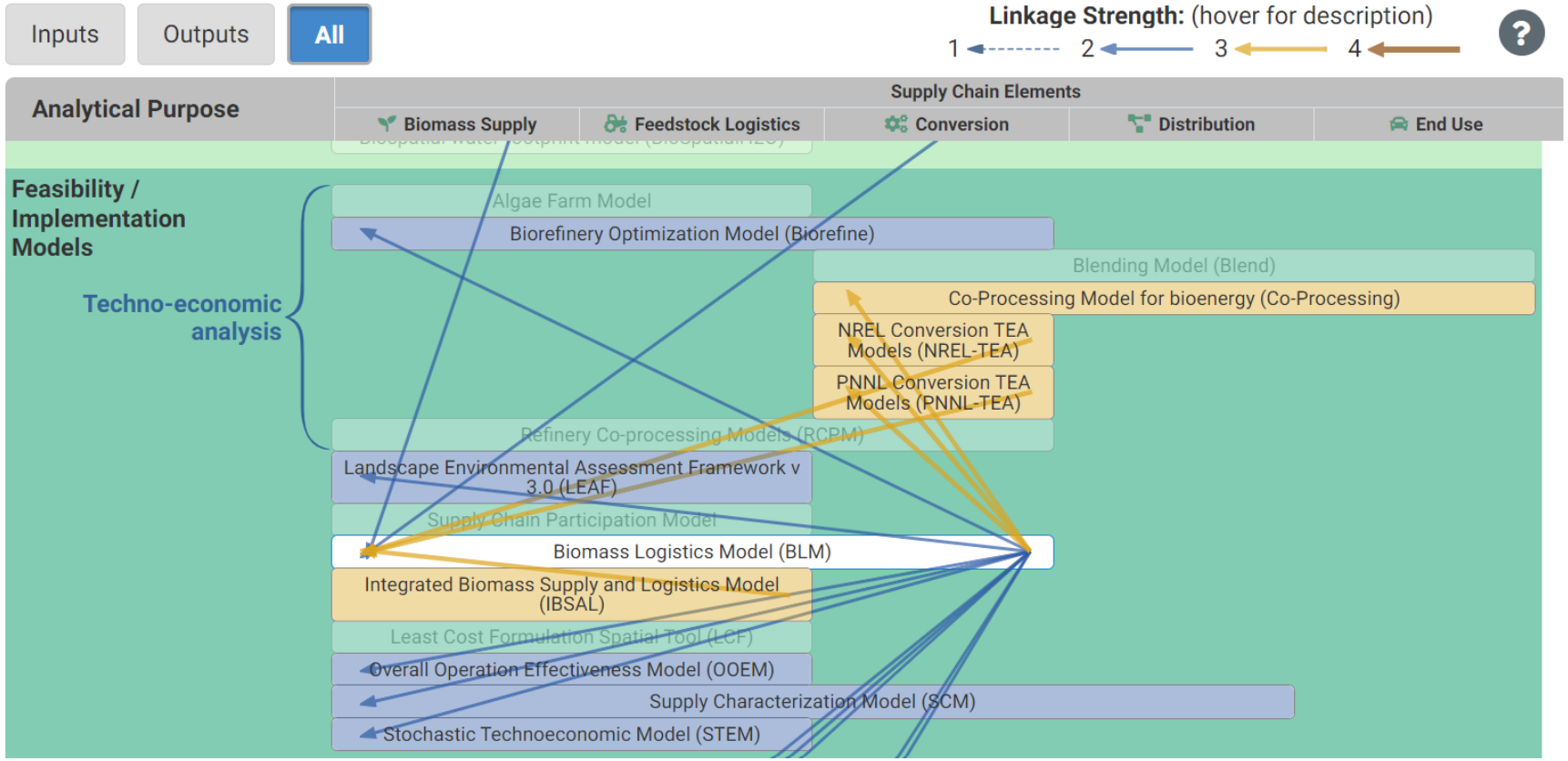
Additional Scenario Analysis

BETO also funds several decision-making tools that take the entire bioenergy supply chain into account to help stakeholders better plan how to meet the goals laid out in the roadmap



The Bioenergy Model Map housed at the National Renewable Energy Laboratory includes details on relevant models across the national lab complex

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Life Cycle Analysis of SAF Fuels – Argonne National Laboratory's GREET

- Argonne National Laboratory is developing a SAF-specific GREET module with user guidance in support of the:
  - Tax credit (40B)
  - Clean Fuel Production Tax Credit (45Z) from the Inflation Reduction Act.
- GREET module will allow SAF producers to submit LCA data and thereby demonstrate eligibility for 40B with U.S. Department of the Treasury as well as determine the credit amount
  - 40B eligibility: 50% LCA GHG reduction
  - 40B Credit Amount: $1.25 (50% reduction) - $1.75 (100% reduction)
- BETO is collaborating with FAA to support this effort

Shutterfly

GREET = The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model

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SAF GC Communications

BETO Communications Lead

Sheila Dillard

Effective Communications and Transparency

Effective communication that transparently demonstrates the environmental, climate, and economic benefits of SAF is vital to building public trust and increasing support.

For the SAF Grand Challenge to be successful, public awareness of SAF as one of the solutions to reduce net GHG emissions from aviation, while also simultaneously investing in the U.S. domestic economy, will be important.

Benefits Include:

- Increases Positive Public Perception
- Counters Misleading, Outdated, Narrow Information
- Helps Build and Maintain Support
- Communicates Impact

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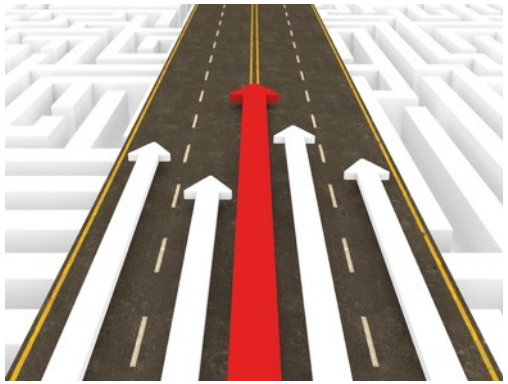
Key Actions to Communicate Progress and Build Public Support

Outreach and engagement with stakeholder groups will continue to be critical for building support and exchanging knowledge to achieve the 2030 goals.

Stakeholder Outreach and Engagement on sustainability to exchange information about best practices to reduce life cycle GHG emissions from agricultural- and forest-derived feedstocks.

Conduct Benefits Assessment/Impact Analysis of SAF Grand Challenge to inform decisions, demonstrate benefits, and mitigate negative impacts.



Measure Progress of the SAF Grand Challenge to provide updates, measure success, and show where progress needs to be made.

Communicate Public Benefits of the SAF Grand Challenge to address common concerns/misconceptions and further build public support.

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SAF Grand Challenge Website

*(**CP.4** Communicate public benefits of the SAF Grand Challenge)*

- Website coming soon, 2023
- Overview of the roadmap
- Links to programs supporting SAF
- Repository for SAF GC information (MOU, factsheets)
- Announcements of events and funding opportunities
- Progress reports

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Q&A with Presenters

Thank you!

Contact us with additional questions & comments at:

eere_bioenergy@ee.doe.gov