Sustainable Aviation Fuel
Grand Challenge Roadmap

To enable the production of 3 billion gallons of SAF per year by 2030 and 35 billion gallons by 2050

SAF Grand Challenge Roadmap Update: Agenda

- Overview & Context
  - SAF Grand Challenge MOU/Timeline/Roles
  - What we need to be successful
  - Inflation Reduction Act
- SAF GC Roadmap - Enabling Industry To Build Out SAF Supply
  - Roadmap purpose and scope
  - Roadmap structure
  - Roadmap action areas and workstreams
- Examples of Implementation
  - Examples of support in all action areas
  - Next Steps

The SAF Grand Challenge

MEMORANDUM OF UNDERSTANDING
SUSTAINABLE AVIATION FUEL GRAND CHALLENGE

Among the
THE U.S. DEPARTMENT OF ENERGY,
THE U.S. DEPARTMENT OF TRANSPORTATION and the
THE U.S. DEPARTMENT OF AGRICULTURE

September 9, 2021

https://www.energy.gov/sites/default/files/2021-09/S1-Signed-SAF-MOU-9-08-21_0.pdf

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
U.S. National Blueprint for Transportation Decarbonization

2030
3 BGY Goal

2050
35 BGY Goal

SAF GC Agency Roles in MOU

DOE

- Continue investments and develop expertise in sustainable technologies to develop cost-effective, low-carbon liquid fuels and enabling coproducts from renewable biomass and waste feedstocks
- Continue a significant multi-year SAF scale-up strategy committed to in FY21
- R&D aimed at creating new pathways toward higher SAF production
- Advance environmental analysis of SAF
- Collaborate with EPA to expedite regulatory approvals of SAF with significant life cycle GHG reductions

DOT/FAA

- Develop overall strategy to decarbonize aviation
- Coordinate ongoing SAF testing and analysis
- Work with standards organizations to ensure safety and sustainability of SAF
- Continue International technical leadership
- Promote end use of SAF
- Support infrastructure and transportation systems that connect SAF feedstock producers, SAF refiners, and aviation end users
- Collaborate with EPA to expedite regulatory approvals of SAF with significant life cycle GHG reductions

USDA

- Continue investments and build expertise in sustainable biomass production systems
- Decarbonize supply chains
- Invest in bio-manufacturing capability and workforce development
- Community and individual education
- Provide outreach and technology transfer to producers, processors, and communities to accelerate adoption and participation
- Commercialization support
- Collaborate with EPA to expedite regulatory approvals of SAF with significant life cycle GHG reductions

https://www.energy.gov/sites/default/files/2021-09/S1-Signed-SAF-MOU-9-08-21_0.pdf

What We Need To Be Successful!

- Create an environment where producers choose to produce and sell SAF
  - Legislative action to reduce cost and risk – IRA!!!
- 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

Inflation Reduction Act - Provisions for SAF

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

SAF tax credits

- Section 13203 Sustainable Aviation Fuel Credit
  - 2-year incentive for those who blend SAF (40B Tax Credit)
  - Sold or used starting on 01/01/2023
- SAF must achieve >50% GHG reduction to be eligible
  - Certified in accordance with CORSIA or similar methodology that satisfies Clean Air Act criteria
- 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 RINs and state LCFS credits
- Section 13704 Clean Fuel Production Credit
  - Subsequent 3-year incentive for those who produce SAF (45Z Tax Credit)
  - Sold or used starting on 01/01/2025

Inflation Reduction Act - Provisions for SAF (continued)

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

Grant program

- Section 40007 – New SAF Projects and Technology Grants
  - $297M to establish “a competitive grant program for eligible entities to carry out projects located in the United States that produce, transport, blend, or store sustainable aviation fuel, or develop, demonstrate, or apply low-emission aviation technologies”.
  - FAA developing two programs – FAST-SAF and FAST-Tech

SAF Grand Challenge Roadmap

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SAF Grand Challenge Roadmap

Released at Global Clean Energy Action Forum on Sept. 23, 2022

- DOE press release
  https://www.energy.gov/eere/bioenergy/articles/sustainable-aviation-fuel-grand-challenge-roadmap-flight-plan-sustainable
- Dept of Transportation press release
  https://www.transportation.gov/briefing-room/dot-joins-energy-and-agriculture-sustainable-aviation-fuel-grand-challenge-roadmap

https://www.energy.gov/sites/default/files/2022-09/beto-saf-gc-roadmap-report-sept-2022.pdf

Roadmap Purpose

A multi-agency plan of federal agency actions that will support stakeholders to build the SAF supply

Derisk technology, supply chains and markets, and reduce barriers:

- Leverage existing government research, development, demonstration, and deployment support
- Accelerate new research, development, demonstration, and deployment support
- Implement a supporting policy framework

SAF GC Roadmap – Structure

Action Areas

1. Feedstock Innovation
2. Conversion Technology Innovation
3. Building Regional SAF Supply Chains
4. Policy & Valuation Analysis
5. Enabling End Use
6. Communicating Progress & Building Support

Action Area Example: Feedstock Innovation

Description: *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.*

Workstreams

Workstreams define critical activities within action area

3 to 6 workstreams per action area. Examples below:

WORKSTREAM FI.1: Understand resource markets and availability *Develop databases and market analysis for commodity and commercially available feedstocks under increased demand for SAF, and assess and analyze the factors effecting the availability of non-commodity/commercial feedstocks*
DELIVERABLE: An understanding of the supply and demand dynamics for feedstocks under the proposed production levels for SAF and development of common databases for SAF feedstocks. IMPACT: Identification of feedstock availability and limitations for SAF conversion technologies and supply/cost curves KEY THEMES: Reduce cost, Expand production
WORKSTREAM FI.2: Maximize sustainable lipid (FOGs) supply for 2030 *Given near term relevance of SAF conversion of lipids to meeting 2030 goals, take a coordinated approach to lipid feedstock R&DDD to support expansion to meet 2030+ goal, development of a lipid multi-generational Project Plan; coordination of USG support for near term lipid crop expansion (e.g. oilseed cover crops)*
DELIVERABLE: More lipids available for HEFA conversion pathway IMPACT: Increase the probability for the production of 3 BG/year SAF by 2030 KEY THEMES: Expanded SAF production (for 2030 goal)

SAF GC Roadmap – Structure

Tables in the Roadmap Appendix provide detailed **Activities** under each Workstream

WORKSTREAM FI.2: Maximize sustainable lipid (FOG) supply for 2030. Given near-term relevance of SAF conversion of lipids to meeting 2030 goals, take a coordinated approach to lipid feedstock RDD&D to support expansion to meet 2030+ goal, development of a lipid project plan, and coordination of U.S. government support for near-term lipid crop expansion (e.g., oilseed cover crops).				
DELIVERABLE: More lipids available for qualified conversion pathways. IMPACT: Increase the probability for the production of 3 billion gal/yr SAF by 2030 and beyond. KEY THEMES: Expand production (for 2030 goal).				
ACTIVITY	**DELIVERABLE**	**IMPACT**	**BEGIN**	**END**
ACTIVITY FI.2.1: Understanding sustainable waste lipid aggregation potential.	Deliver data and analysis of costs, quantities, and location for optimization of diverse lipid aggregation for regional SAF production.	Increased lipid feedstock to meet 2030 SAF production goals.	2023	2030
ACTIVITY FI.2.2: Identifying sustainable lipid feedstock potential from industrial effluents and byproducts.	A report outlining the identity, quality, quantity, and cost of lipid feedstock from industrial effluents and byproducts.	Increased lipid feedstock to meet 2030 SAF production goals.	TBD	TBD
ACTIVITY FI.2.3: Expanding potential for existing sustainable oilseed/row crop production.	A report outlining the identity, quality, quantity, and cost of lipid feedstock from expanded oilseed crop production. Strategies on the use of oilseed cover crops and crop rotations that allow for the increase in vegetable oil production without	Increased lipid feedstock to meet 2030 SAF production goals.	TBD	TBD

SAF GC Roadmap - Summary

- 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
- 2030 & 2030-2050 impact timeframes

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 (harvest/collection, transport, storage, preprocessing

FI.5 Increase reliability of feedstock handling systems

FI.6 Improve sustainability of biomass and waste supply systems

Action Area: Conversion Technologies and Processes (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 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 Workstreams

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

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

CT.3 Develop bio-intermediates 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

Action Area: Building Regional Fuel Supply Chains (SC)

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

Supply Chains Workstreams

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

SC.2 Model SAF supply chains

SC.3 Support demonstration of regional SAF supply chains

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

Action Area: Policy & Valuation Analysis (PA)

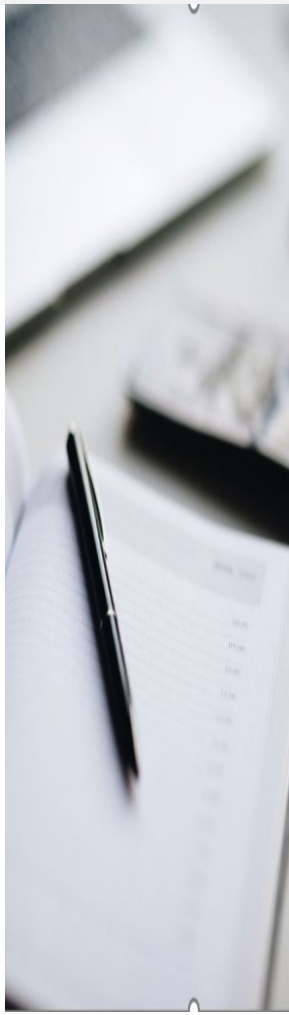
Provide data, tools, and analysis to support policy decisions and maximize social, economic, and environmental value of SAF including evaluation of existing and new policies.

Policy & Valuation Analysis Workstreams

PA.1 Improved environmental models and data for SAF

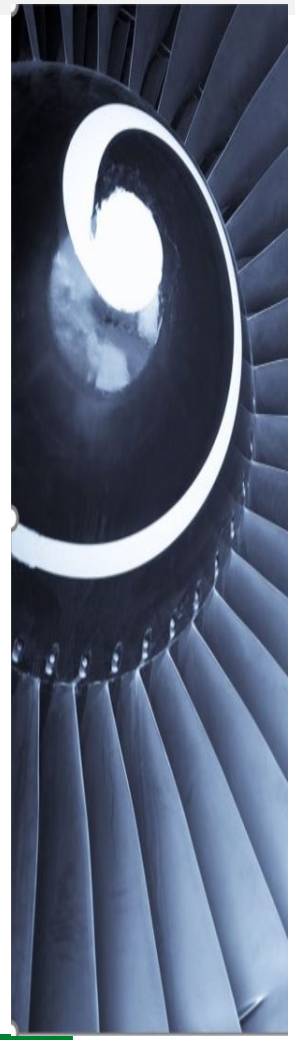
PA.2 Conduct techno-economic and production potential analysis

PA.3 Inform SAF policy development



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

Action Area: Communicating Progress & Building Support (CP)

Monitor and measure progress against SAF GC goals, provide public information resources, and communicate the public benefits of the SAF GC to critical stakeholders and the public.

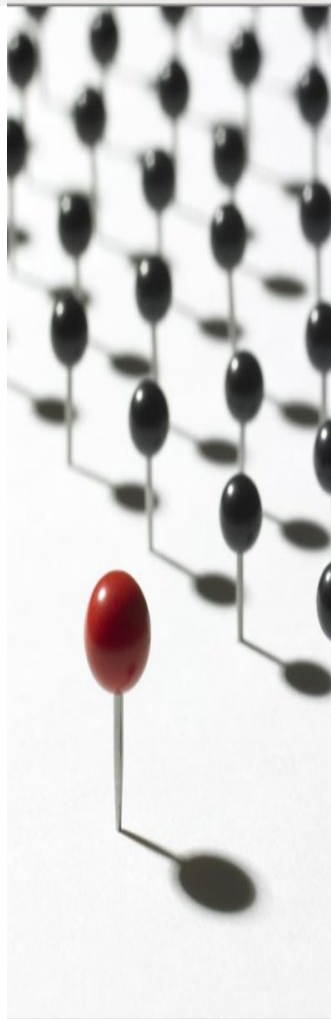
Communicating Progress & Building Support Workstreams

CP.1 Stakeholder Outreach and Engagement on Feedstock Sustainability

CP.2 Conduct benefits assessment/impact analysis of the SAF Grand Challenge

CP.3 Measure progress of the SAF Grand Challenge

CP.4 Communicate public benefits of the SAF Grand Challenge



Examples of Implementation

To enable the production of 3 billion gallons of SAF per year by 2030 and 35 billion gallons by 2050

SAF GC Roadmap - Summary

- Six Action Areas
  1. **Feedstock Innovation (FI)**
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  5. **Enabling End Use (EU)**
  6. **Communicating Progress and Building Support (CP)**

Update on National Institute of Food and Agriculture SAF Feedstock-relevant Coordinated Agricultural Projects (CAPs)

(FI.2; FI.3; FI.6)

- IPREFER Pennycress Oilseed Cover Crop CAP
  - Genetically modified pennycress (native weed) >>> Golden pennycress (oilseed cover crop)
  - Produces oil for SAF or RBD, meal for livestock feed
  - Western IL U, CoverCress, Inc., Southern IL U
  - On the cusp of commercialization
    - 8,000 pilot acres planted Fall 2022
    - Strong farmer interest
  - Solid investment backing
    - Covercress purchased by Bayer (now a self-standing subsidiary)
    - Commercial relationship with Ag giant Bunge
    - Commercial relationship with REG (now part of Chevron)
  - Vast scaling potential in Midwest, upper Midwest

Update on National Institute of Food and Agriculture SAF Feedstock-relevant Coordinated Agricultural Projects (CAPs)

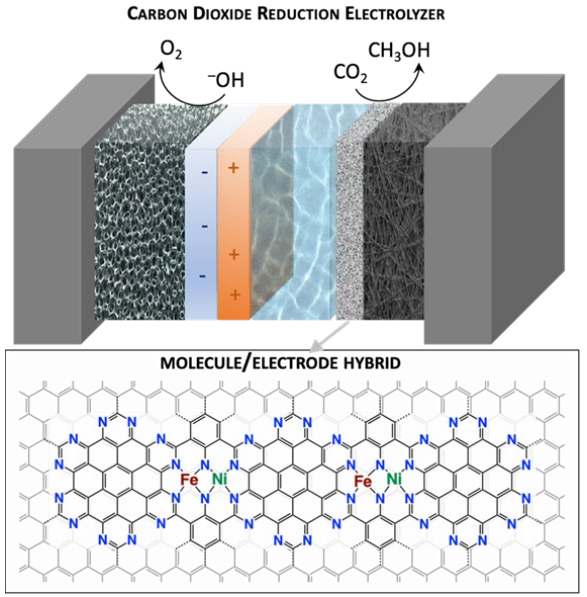
- SPARC *Brassica carinata* (Carinata) Oilseed Cover/Rotation Crop CAP **(FI.2; FI.3; FI.6)**
  - Carinata non-GMO oilseed cover/rotation crop
  - Produces oil for SAF or RBD, non-GMO meal for livestock feed
  - U Florida, Nuseed, Inc., ARA
  - On the cusp of commercialization
    - Strong GHG reduction potential
    - Solid agronomics and demonstrations
    - Strong farmer interest
    - Strong market in EU for livestock meal
    - First crop in a decade or more approved for RINS by EPA!!
  - Solid investment backing
    - Nuseed signed commercial development agreement with BP
  - Good scaling potential in Southeast crop rotations

USDA

CO2 Utilization R&D by BETO

(CT.2 Develop options to increase production and reduce carbon intensity of ASTM-approved pathways)

- Converting Carbon Dioxide into Affordable Biofuels and Bioproducts
  - Research at Argonne National Laboratory (ANL) and National Renewable Energy Laboratory (NREL) seeks to develop carbon dioxide utilization technologies to make SAF and other useful products
  - Goal is to identify catalysts that can make SAF efficiently
  - Tasks include electrochemical method to convert CO2 to methanol, catalyst development, electrolyzer assembly and scale-up
  - Designing catalysts with molecular electrodes that exhibit high selectivity for methanol
  - Methanol can be used in fuel cells, boilers, and as blend-stock for transportation fuels
  - Methanol converted to fuels using microorganisms and algae using renewable electricity



SAF Feedstocks (SC.1; SC.3)

- **The GEVO Climate-Smart Farm-to-Flight Program (Links to the Sustainable Aviation Fuel Grand Challenge)**

- The project aims to create critical structural climate-smart market incentives for low carbon-intensity corn as well as to accelerate the production of sustainable aviation fuel to reduce the sector's dependency on fossil-based fuel. This project includes an immediate market opportunity to sell climate-smart, low-climate-impact corn.

- **Lead Partner:** Gevo, Inc.

Other Major Partners: Southwest Iowa Renewable Energy, LLC, Google, Farmers Edge, EarthOptics, South Dakota State University, Regen Ag Labs, Yard Stick, Double H Ag Services, Farmers Edge, AgSpire, PrairieFood, Stine Seed Farm, Holganix, Trace Genomics, MidState Agronomy, Double H Ag Services, Colorado State University, Iowa State University, Standing Rock (SAGE) Renewable Energy Power Authority
Primary States Expected: MN, SD, NE, IA, Tribal
Major Commodities: Corn

- **Approximate Funding Ceiling:** $30,000,000

Major Oilseed Crop: Soybean (SC.1; SC.3)

- **Midwest Climate-Smart Commodity Program**
- This project will build markets and provide funding to farmers via outcome-based contracts for the reduction and removal of carbon dioxide through the adoption of new climate-smart practices. The remaining project funding will support farmer enrollment assistance, carbon quantification, technical assistance support, measurement, reporting and verification, and underserved farmer outreach and enrollment.
- **Lead Partner:** Iowa Soybean Association
  Other Major Partners: ReHarvest Partners, PepsiCo, Cargill, Renewable Energy Group, Ingredion, Target, JBS, Coca-Cola, Mano y Ola, FarmRaise, Rural Community Assistance Partnership
  Primary States Expected: IL, IN, IA, KS, NE, ND, OH, WI, SD, MO, MI, MN
  Major Commodities: Corn, Soybeans, Wheat
- **Approximate Funding Ceiling:** $95,000,000

Oilseed Cover Crop/Rotational Crop: Camelina (SC.1; SC.3)

- **Climate-Smart Camelina**
- This large-scale pilot project aims to measure and validate the climate-smart advantages of Camelina sativa (L.) in both rotational and winter cover crop production systems and build associate climate-smart biofuels markets. The project will accelerate farmer adoption of camelina as a non-food crop grown on idle acres to produce more plant-based feedstock for renewable biofuels and chemicals with low carbon intensity and no land-use change while increasing carbon capture in the soil.
- **Lead Partner:** Global Clean Energy Holdings, Inc.
  Other Major Partners: Sustainable Oils, Bakersfield Renewable Fuels, ExxonMobil, Farmobile/AGI, Davis Instruments, Pessl Instruments, EarthDaily Agro, Intelinair, Earth Optics, Yard Stick, ARVA Intelligence
  Primary States Expected: ID, CO, KS, MO, MT, OK, OR, TX, WA, WY, Tribal
  Major Commodities: Camelina
- **Approximate Funding Ceiling:** $30,000,000

Supply Chain Analysis and Tools

(**SC.1** Build and support regional stakeholder coalitions through outreach, extension, and education; **SC.2** Model SAF supply chains)

ASCENT Projects

- A001 Alternative Jet Fuel Supply Chain Analysis
- A093 Collaborative Research Network for Global SAF Supply Chain Development

Supply chain tool

- Freight and Fuels Transportation Optimization Tool (FTOT) – DOT Volpe Center

From Strain Development to Commercial Operation

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

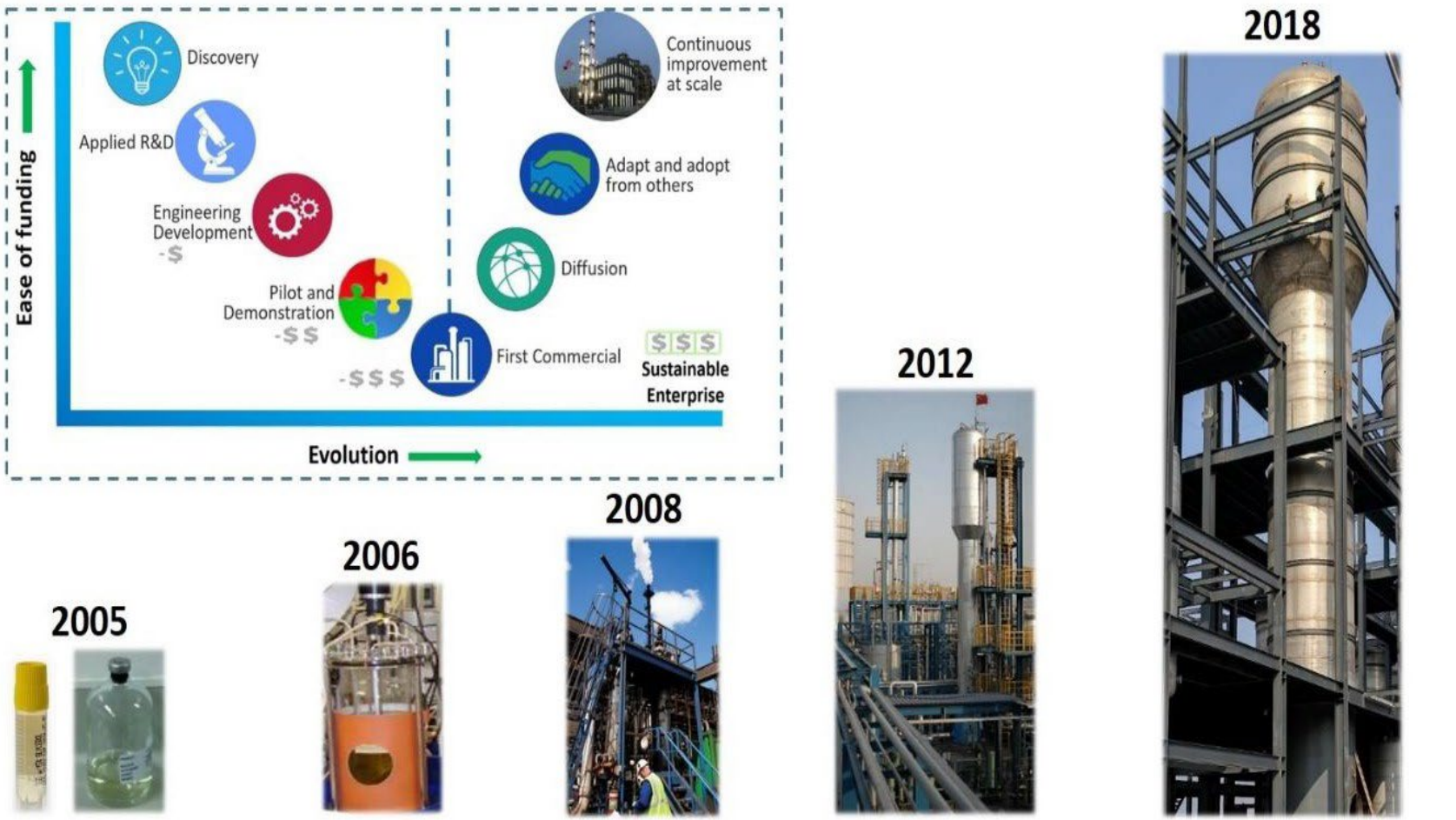


Image courtesy of LanzaTech

URGENT: Expand the emerging industry

- **TODAY:** ~25 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

Spotlight: Fulcrum BioEnergy Ltd

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

- MSW to fuels production begins at Fulcrum's Sierra BioFuels Plant
  - Production began in December 2022 at the plant near Reno, Nevada, making it the first and largest waste-to-fuels plant
  - Now preparing to supply their strategic partners with synthetic crude oil product, a step forward for SAF Grand Challenge goals
  - Fulcrum now developing two more waste-to-fuels plants, one in Indiana and the other in the UK in conjunction with Essar Oil

Right: Fulcrum's Reno, Nevada Plant
Left: Rendering of future plant design in Gary, Indiana

Images courtesy of Fulcrum

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
  - Focused on domestic GHG LCA needs
  - Identify best practices and understand why different methods give different estimates of emissions
  - Examination of 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.

FAA Certification & Qualification Support

(**EU.1** Support SAF evaluation, testing, qualification and specification;
EU.2 Enable Use of Drop-In Unblended SAF and SAF Blends up to 100%)

ASCENT Projects

- A031 Alternative Jet Fuels Test and Evaluation
- A025 National Jet Fuels Combustion Program – Area #1: Chemical Kinetics Combustion Experiments
- A065A Fuel Testing Approaches for Rapid Jet Fuel Prescreening
- A088 A Method for Rapidly Assessing Jet Fuel Compatibility with non-Metallic Materials
- A089 Characterization of Compositional Effects on Dielectric Constant

CLEEN

- Boeing & GE Aviation

FAST-SAF Grant Program

(**EU.4** Integrate SAF into fuel distribution infrastructure)

- Fueling Aviation's Sustainable Transition (FAST) SAF & Technology competitive grant program
- Section 4007 of Inflation Reduction Act of 2022
- for U.S. projects that "produce, transport, blend, or store sustainable aviation fuel"
  - $244.5 million for projects relating to SAF production, transportation, blending, or storage
  - $46.5 million for projects relating to low-emission aviation technologies
  - $5.9 million to fund grant award program administration
- Objective - make investments to accelerate the production and use of SAF, thereby supporting the goals of the SAF Grand Challenge, to meet U.S. aviation climate goals to reduce aviation carbon emission
- Public Meeting held on December 14, 2022
- Grant program organization and NOFO in development
- Receiving comments at FAST-SAFTECH@faa.gov

https://www.transportation.gov/mission/office-secretary/office-policy/aviation-policy/fueling-aviations-sustainable-transition

SAF Grand Challenge Website

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

- Website under development to be hosted at biomassboard.gov
- Overview of the Roadmap
- Links to programs supporting SAF
- Repository for SAF GC information (MOU, Factsheets)
- Announcements of events and funding opportunities
- Progress reports
- Launch anticipated Q2 of 2023

Roadmap Implementation – Next Steps

- Federal agencies
  - Inventory and map existing and planned activities aligned with roadmap
  - Identify RDD&D gaps and funding needs
- Stakeholder engagement
  - Obtain external stakeholder input on federal activity plans
  - Provide recommendation 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

Thank You!

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