Accelerating Sustainable Aviation Fuel Technology From Laboratory to Deployment

An Overview of NREL's Sustainable Aviation Fuel Pathways

NREL's multireactor system is used to evaluate renewable and waste resource conversion into fuels and chemicals.

The National Renewable Energy Laboratory (NREL) develops and de-risks a portfolio of technologies for converting renewable carbon resources into sustainable fuels, including sustainable aviation fuel (SAF).

NREL works with industry, academia, and other national laboratories to develop, scale, and de-risk technology pathways for producing SAF from renewable resources such as biomass and other forms of waste carbon, including carbon dioxide (CO_2).

De-Risking and Scaling Mature SAF Technologies

NREL partners with key stakeholders to move high technology readiness level (TRL) technologies out of the laboratory and into the marketplace.

NREL's process development strategy includes rigorous techno-economic analysis (TEA) and life cycle assessment (LCA) at every step in the research and development (R&D) process to assure cost-effective and sustainable outcomes.

Following are examples of SAF pathways currently being scaled at NREL and with industry partners.

SAF From Advanced Pyrolysis Oil

Research partners: Alder Renewables; United Airlines; Honeywell UOP; Avfuel Corporation; U.S. Department of Defense; U.S. Department of Energy

Feedstock: Woody biomass, agricultural residues

- Produces carbon-negative Alder Renewable Crude
- Can be hydrotreated using existing refinery infrastructure to minimize capital and time-to-market.
- Resulting SAF blendstock rich in cycloparaffins and aromatics, meeting relevant ASTM fuel property standards.

SAF From Cellulosic Ethanol

Research partners: D3MAX; U.S. Department of Energy; Southwest Airlines; LanzaJet; Novozymes; SAFFiRE Renewables

Feedstock: Corn stover

- NREL deacetylation and mechanical refining process, combined with enzymatic hydrolysis, produces a low-carbon ethanol intermediate for upgrading to SAF.
- Project being demonstrated in a fully integrated, 10 ton-per-day pilot plant.

Improving Technologies in the Pipeline to Market

NREL's extensive applied R&D capabilities are employed to prove the commercial viability of SAF technologies.

NREL partners with industry to scale integrated SAF technology pathways in our sophisticated pilot facilities (www.nrel.gov/bioenergy/facilities.html) while carrying out TEA and LCA to guide R&D efforts.

Following are examples of SAF pathways under development at NREL.

SAF From Soluble Sugars

Research partners: Virent; University of Colorado, Boulder; Shell

Feedstock: Cellulosic sugars (feedstock flexible)

- Project de-risks and develops Virent's catalytic conversion of sugars to low-carbon SAF, including constructing and operating an integrated process.

NREL's **Davison Circulating Riser reaction system** for investigating catalytic cracking of biogenic feedstocks in a realistic industry environment.

- Integrates catalytic conversion technology with NREL's deacetylation and mechanical refining process for producing cellulosic sugars from biomass.

SAF From Anaerobic Digestion

Research partners: Alder Renewables, Colorado State University; Fluent Renewables Inc.; Quasar Energy Group

Feedstock: Volatile fatty acids (VFAs) from arrested anerobic digestors

- NREL catalytic technology upgrades neat VFAs to ketones, which can be upgraded to a carbon-negative SAF blendstock.
- Offers "bolt-on" solution for existing anerobic digestor systems.

SAF From Hydrotreated Bio-Oil

Feedstock: Biomass, waste carbon from biogenic sources

- Catalytic fast pyrolysis technology converts feedstocks to SAF by hydrotreating stabilized bio-oil, achieving >70% reduction in modeled greenhouse gas emissions compared to petroleum-derived fuel.
- Biochar byproduct sequesters carbon for additional credits.
- Refinery integration and co-processing with fossil feedstocks reduces risks, provides trained workforce, and saves on capital cost by leveraging existing infrastructure.
- Provides cycloparaffins and aromatics, which complement SAF made from hydroprocessed esters and fatty acids.

SAF From Fluid Catalytic Cracker Co-Processing

Feedstock: Lignocellulosic biomass

- Uses ex situ catalytic fast pyrolysis to produce a mildly upgraded bio-oil suitable for co-processing in existing petroleum refinery fluid catalytic cracking unit operations.
- Resulting SAF contains >80% of biogenic carbon in the feed.

SAF and High-Octane Gasoline From Syngas in a Single Reactor

Feedstock: Syngas from biomass gasification

- Yields energy-dense hydrocarbons in one step instead of three using NREL's patented Cu-modified beta zeolite catalyst.
- Transitioning process to target SAF after success with high-octane gasoline from dimethyl ether.
- Co-conversion of CO_2 with syngas increases carbon efficiency.

Developing Technologies for Future Industry Partnerships

NREL's lower TRL R&D offers a pipeline for commercializing novel, new technologies and process pathways.

Industry can access and license NREL's innovations in the intellectual property portfolio to explore and capitalize on their market potential.

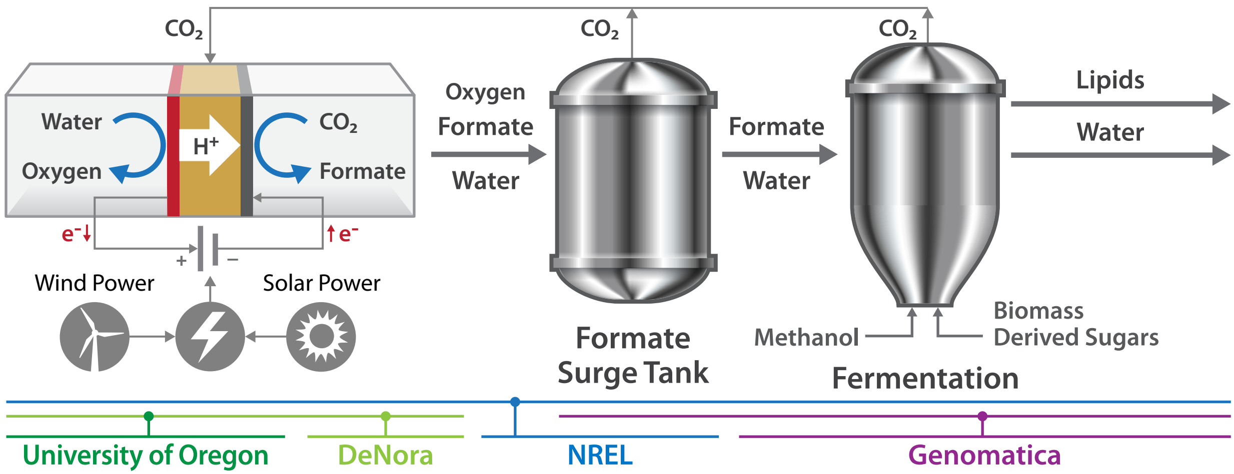
Following are examples of lower TRL R&D the NREL team is studying.

SAF From Reductive Catalytic Fractionation of Biomass

Feedstock: Lignocellulosic biomass

- Converts lignin to aromatic and cycloalkane blendstocks, achieving >90% mass balance and <1 wt% oxygen from poplar feedstocks.
- Controls selectivity to aromatic or saturated products.

NREL is developing technology for producing lipids from cellulosic sugars with carbon capture and utilization to produce carbon-negative products.



SAF From Fermentation Incorporating Carbon Capture and Utilization

Feedstock: CO_2, water

- Novel pathway combines electrochemical conversion of CO_2 with fermentation of cellulosic sugars and other carbon sources, incorporating carbon capture and CO_2 recycling/utilization.
- Chemical looping system leverages intermittent, low-cost electricity from wind and solar resources.

SAF From Combined Algal Processing

Feedstock: Algal biomass

- Process produces lipids, carbohydrates, and residues from algae to yield SAF precursors and materials for manufacturing non-isocyanate polyurethanes.
- Lipids from algae are fungible feedstocks for hydroprocessed esters and fatty acids (HEFA) biorefineries, while carbohydrates can be deconstructed and fermented to produce cellulosic ethanol.

Work With Leading NREL SAF Researchers

Leverage NREL expertise and capabilities by joining a public-private partnership to drive innovation for tomorrow's SAF.

NREL's slate of flexible research agreements are designed to accelerate commercialization, protect intellectual property, and spur innovation in SAF and other bioenergy technologies.

Learn more:
nrel.gov/bioenergy/work-with-us.html

For more information or collaboration opportunities, contact:

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NREL Transforming ENERGY

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