DOE Bioenergy Technologies Office (BETO)
2021 Project Peer Review

Opportunities in BioJet

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in collaboration with Georgia Tech, LANL, NREL, PNNL, U. Dayton

March 22, 2021

This presentation does not contain any proprietary, confidential, or otherwise restricted information

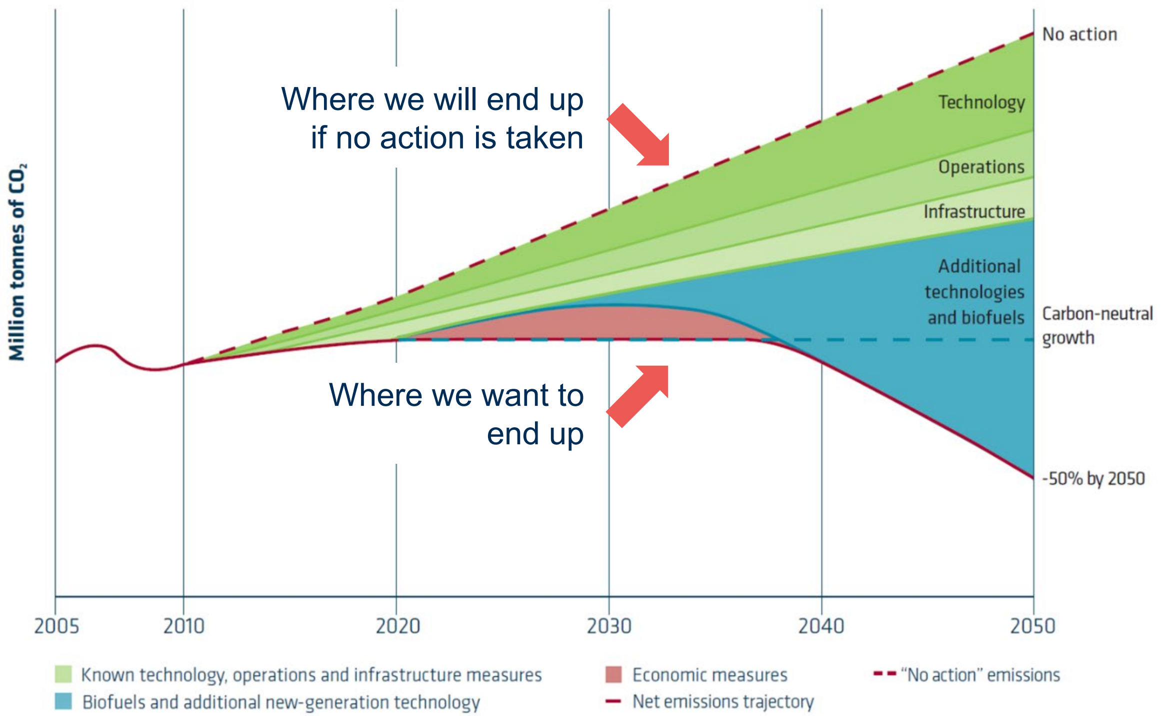
Overview

Sustainable aviation fuel [SAF] deployment is critical for meeting industry targets

- **Substantial growth** in air travel by 2050
- **ICAO/Industry Goal:** Aviation CO_2 emissions impact to be returned to 2005 levels by 2050
- International Air Transport Association (IATA) in 2009 set a goal of 50% reduction in CO_2 emissions relative to 2005 levels
- Up to 75% of the emissions growth by 2050 is offset by SAF and/or carbon off-sets
- Electrification will be limited; viable feedstocks and SAFs need to be developed and deployed

***SAF –Sustainable aviation fuels**

IATA Technology Roadmap 2013



Where we will end up if no action is taken

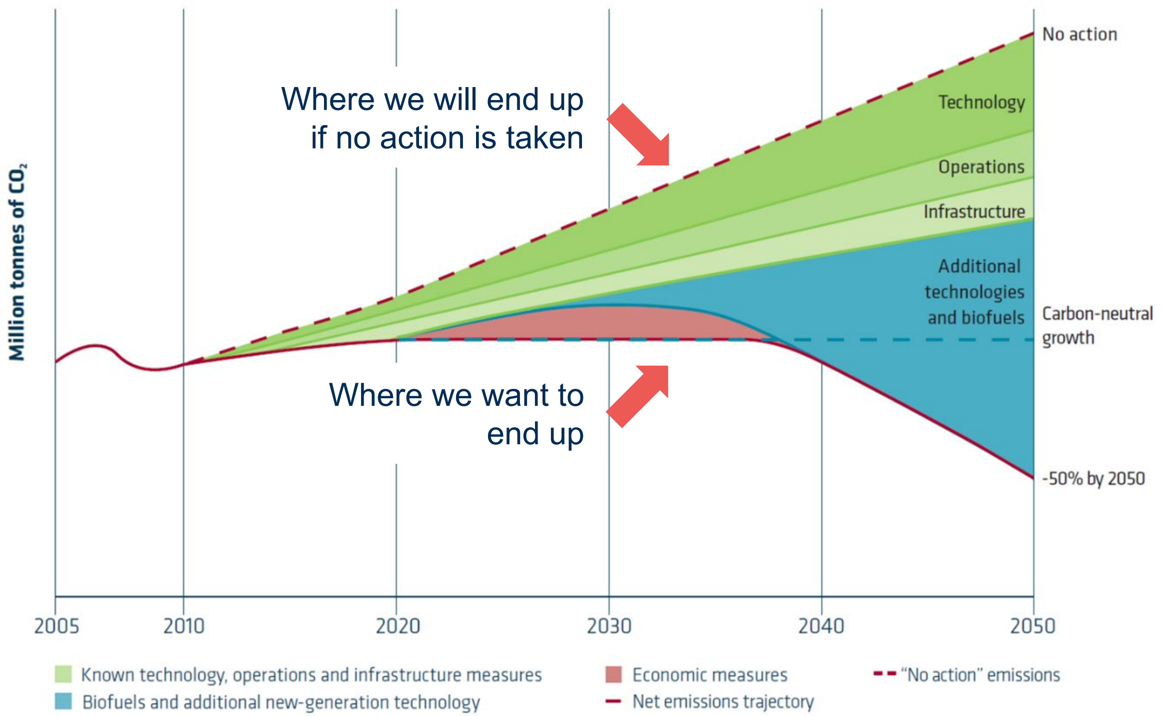
Where we want to end up

Overview

This project aims to remove technical and analysis barriers to SAF deployment

- **Goal:** Address key roadblocks to deploying new sustainable aviation fuels
  - What molecules and blends are optimal?
  - How can we reduce costs associated with SAF?
  - What is the value proposition of these SAF to industry?
- **Outcome:** Provide foundational knowledge needed by stakeholders for SAF deployment
- **Relevance:** Technology to meet aggressive international aviation targets for CO_2 reductions and BETO's biofuel goals

IATA Technology Roadmap 2013

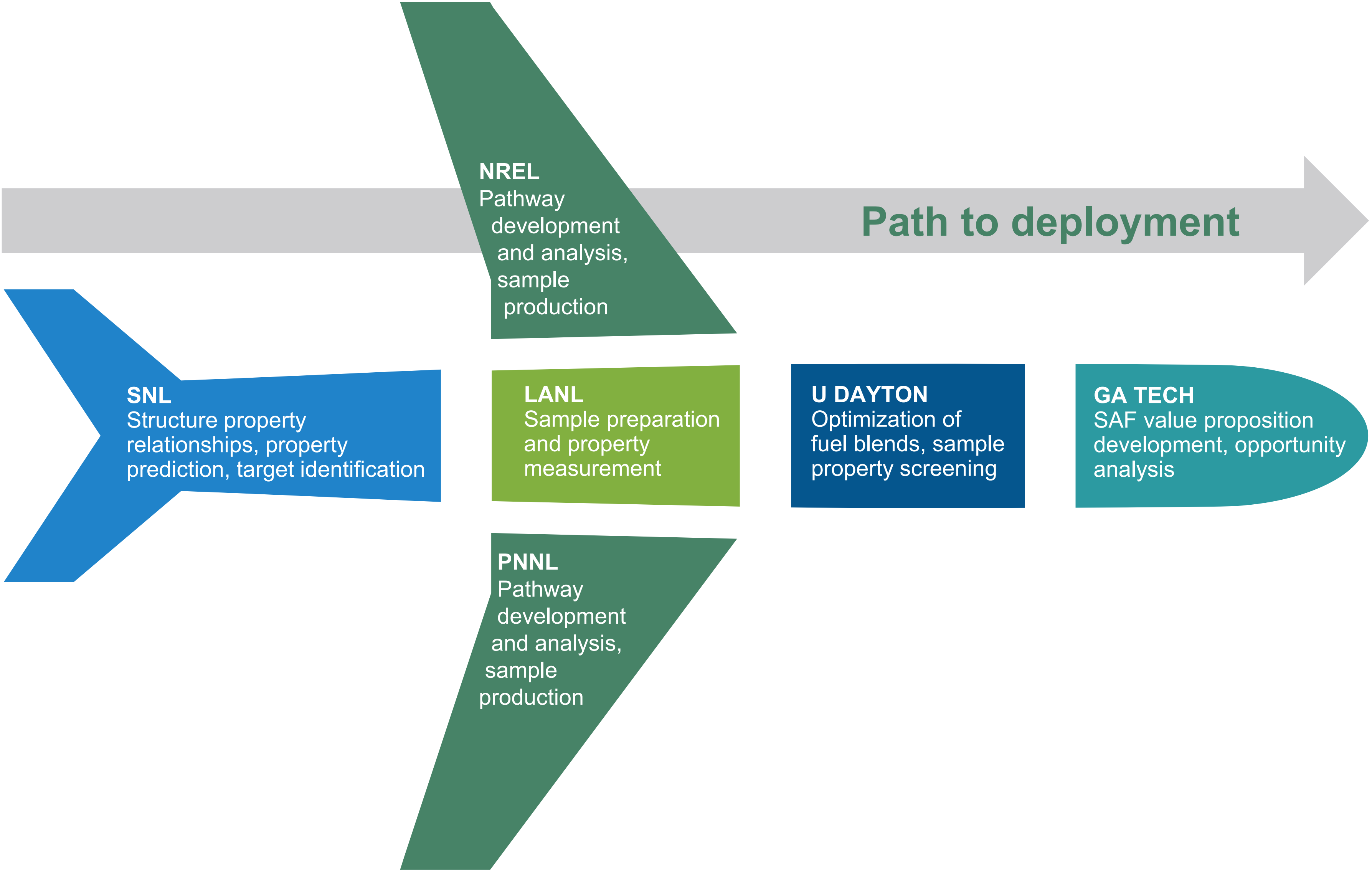


Where we will end up if no action is taken

Where we want to end up

1. Management

A team of national labs and academia driving towards common goals



Path to deployment

NREL
Pathway development and analysis, sample production

SNL
Structure property relationships, property prediction, target identification

LANL
Sample preparation and property measurement

U DAYTON
Optimization of fuel blends, sample property screening

GA TECH
SAF value proposition development, opportunity analysis

PNNL
Pathway development and analysis, sample production

1. Management

Strong co-ordination and communication ensure objectives are met

- Structured meetings, centralized information sharing and stakeholder engagement keep the project organized and on track
- Tiered meetings
  - Annual kick off meeting
  - Monthly report-outs
  - Regular sub-group meetings
- Box platform for data sharing and collection
- Slack channels for impromptu topical discussions
- Information dissemination via conferences, outreach and scientific reports and publications

1. Management

Strong co-ordination and communication ensure objectives are met

Key relationships with broad spectrum of stakeholders

- Airlines of America
- Atlanta Hartsfield Jackson Intl. Airport
- Delta and other airlines
- Port of Seattle
- FAA Office of Environment and Energy
- ICAO Committee on Aviation Env. Protection
- General Electric
- Boeing
- CAAFI
- Colonial and Plantation pipelines (upcoming)

Strong ties to other DOE offices and programs: BETO and beyond

Agile BioFoundry

JBEI
Joint BioEnergy Institute

BIOPROCESSING SEPARATIONS CONSORTIUM

Co-Optimization of Fuels & Engines

ChemCatBio

1. Management

Risks to technical challenges are identified and mitigated

Risks	Risk mitigation
Computational models are not fully predictive for important properties	Selected fuels are measured to verify actual properties, and discrepancies are used in model improvements
Predicted biofuel cost cannot be reduced to achieve parity with incumbent	System modeling is used to identify selected biofuel/ conventional blends and ratios that increase overall value

2. Approach

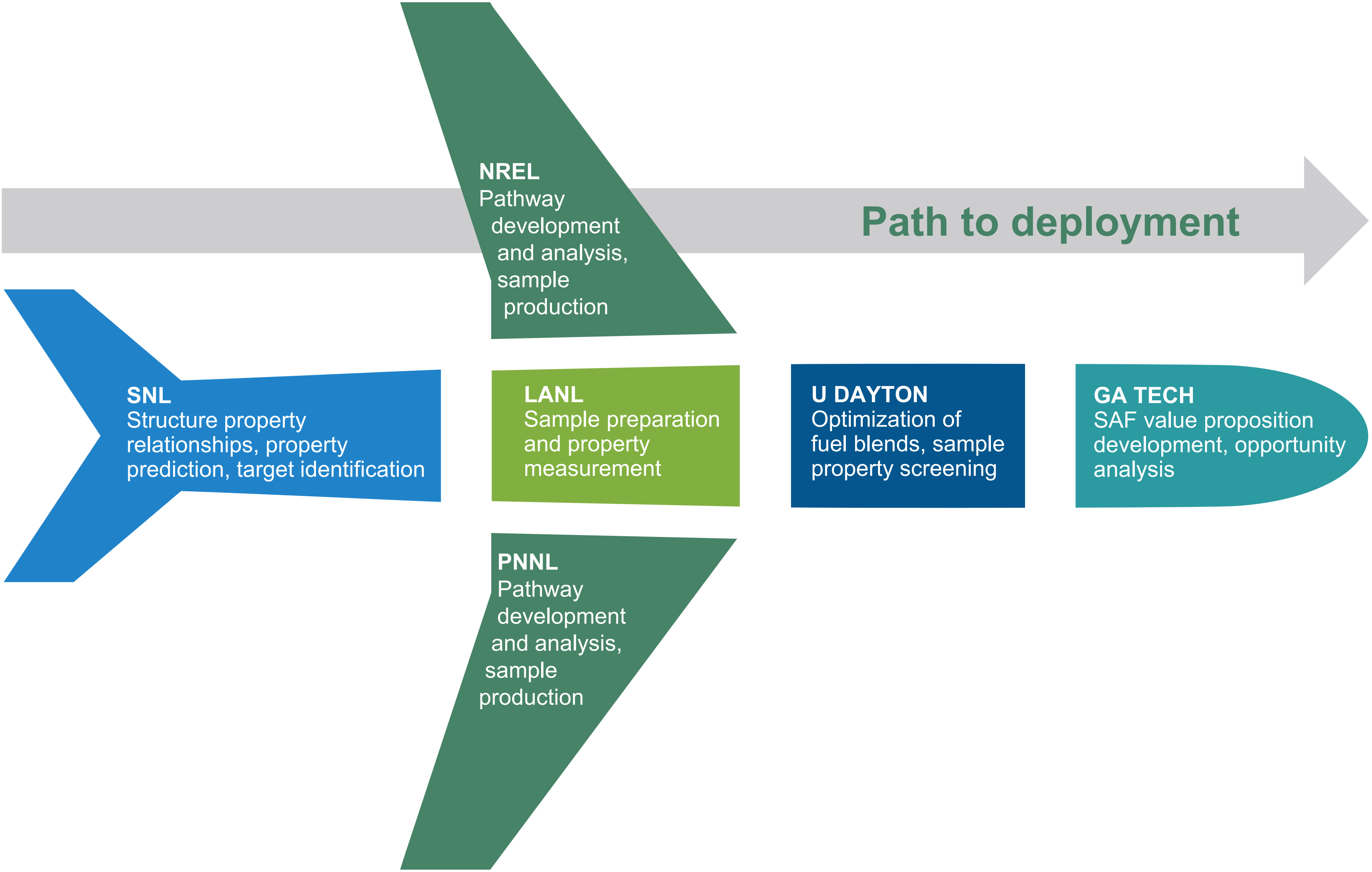
BETO Sustainable Aviation Fuel Workshop report guides approach

What molecules and blends are optimal?	How can we reduce SAF production costs?	What is the value proposition to industry?
● Develop structure-property knowledgebase to facilitate improvements in performance while maintaining operational specifications ● Identify promising biologically-derived molecules that increase fuel performance	● Employ low-cost wet-waste feedstocks with conversion chemistry selected for jet-compatibility ● Exploit efficient, tunable ethanol-to-jet conversion technology	● Employ systems modeling at vehicle and fleet level ● Quantify biofuel benefit to meeting CO_2 targets ● Optimize locations of biofuel production for greatest benefit ● Quantify value conferred by increased performance

2. Approach

Complementary capabilities result in a natural work flow

- **Property modeling**
- **SAF screening**
- **Blend optimization**
- **Pathway development**
- **Systems analysis**



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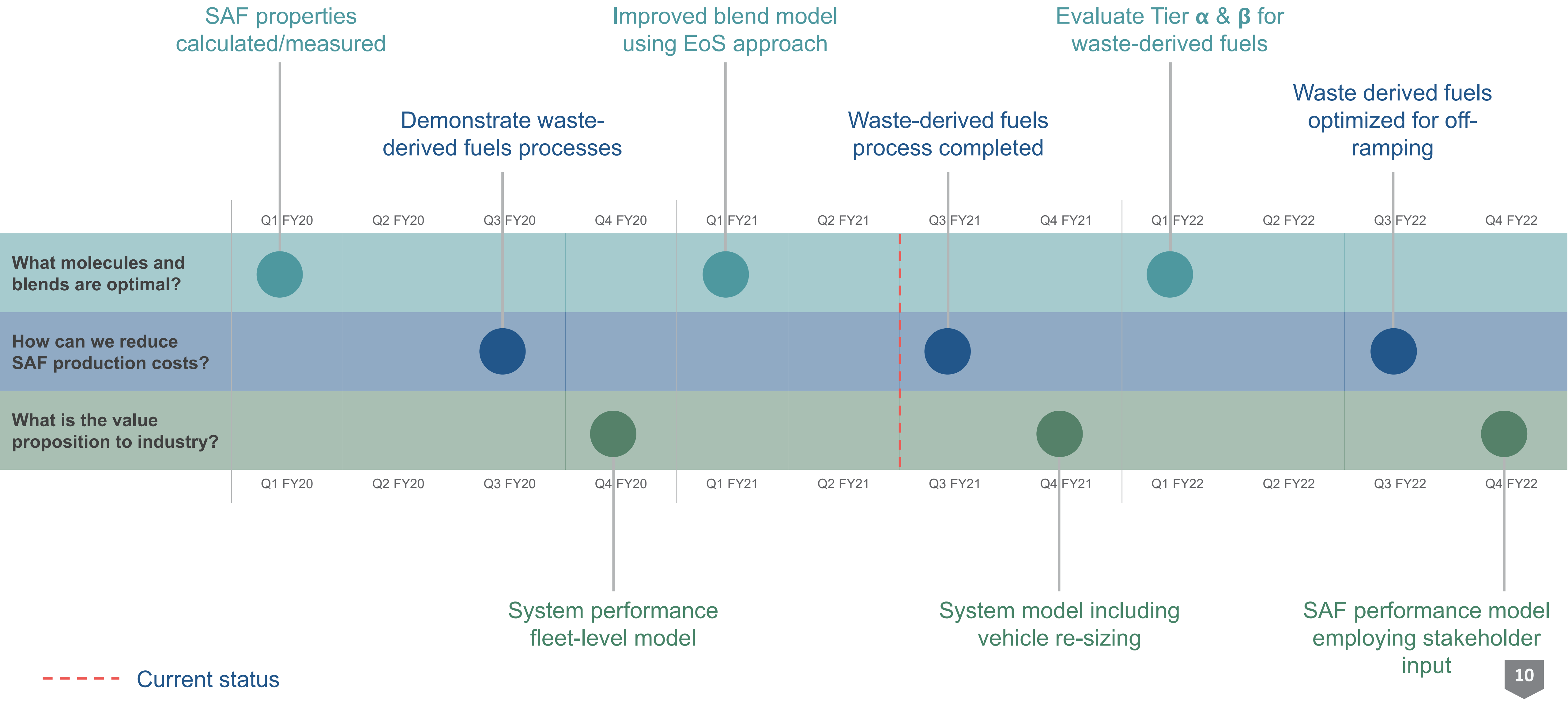
2. Approach

High-level milestones enable targeted progress



SAF properties calculated/measured

Improved blend model using EoS approach

Evaluate Tier **α** & **β** for waste-derived fuels

Demonstrate waste-derived fuels processes

Waste-derived fuels process completed

Waste derived fuels optimized for off-ramping

Q1 FY20 Q2 FY20 Q3 FY20 Q4 FY20 Q1 FY21 Q2 FY21 Q3 FY21 Q4 FY21 Q1 FY22 Q2 FY22 Q3 FY22 Q4 FY22

What molecules and blends are optimal?

How can we reduce SAF production costs?

What is the value proposition to industry?

Q1 FY20 Q2 FY20 Q3 FY20 Q4 FY20 Q1 FY21 Q2 FY21 Q3 FY21 Q4 FY21 Q1 FY22 Q2 FY22 Q3 FY22 Q4 FY22

System performance fleet-level model

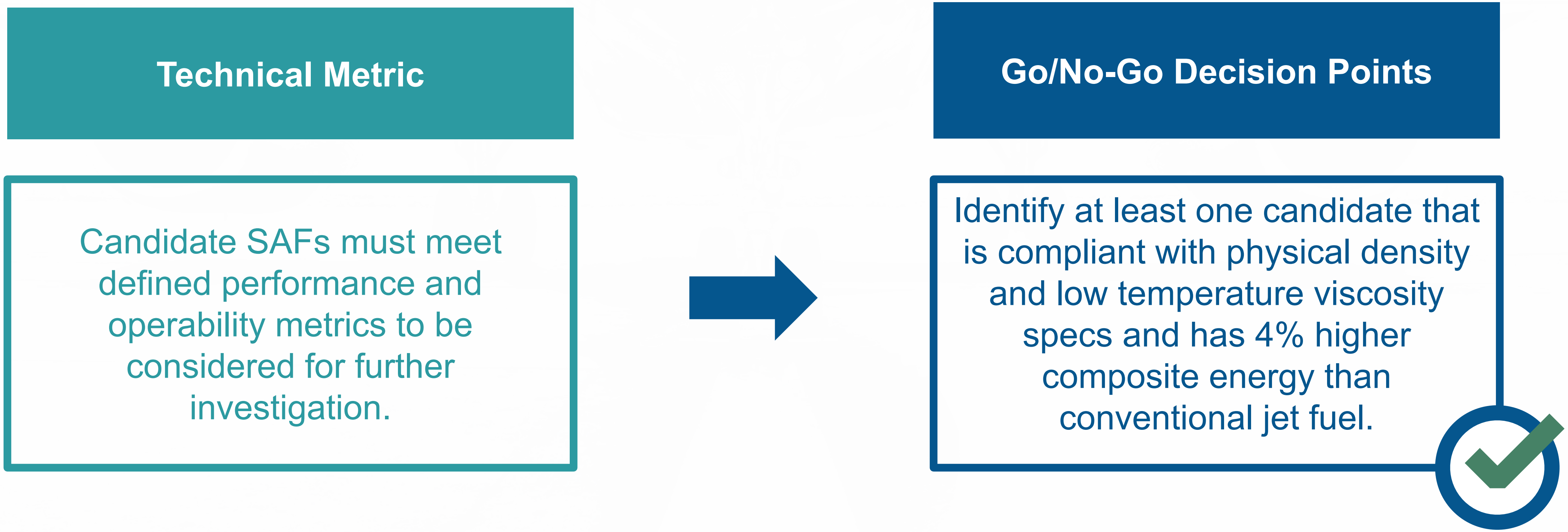
System model including vehicle re-sizing

SAF performance model employing stakeholder input

Current status

2. Approach

Metrics and Go/No-Go decisions for main technical challenges ensure progress



Technical Metric

Candidate SAFs must meet defined performance and operability metrics to be considered for further investigation.

Go/No-Go Decision Points

Identify at least one candidate that is compliant with physical density and low temperature viscosity specs and has 4% higher composite energy than conventional jet fuel.

3. Impact

Advancing technical state-of-the-art and giving stakeholders deployment options

- Fuel developers will be able to answer “what if” questions regarding innovative new molecules and blends
  - Optimization of fuel composition to meet physical property specifications will be possible
  - Stakeholders will be able to compare operational benefits from different fuel choices in a streamlined manner
- Novel SAFs will be poised to enter the ASTM D4054 process for approvals ranging from 10% to 50% blend ratios with conventional fuel

- Presentations and publications are targeted for impact with relevant stakeholders and the broader scientific community
  - Commercial Alternative Aviation Fuel Initiative (CAAFI) community via webinars and committee meetings
  - Publications in leading journals [PNAS, FUEL and AIAA SciTech];
  - Presentations and contributions at ACS, CRC, the EU Commission, international research institutions and other workshops

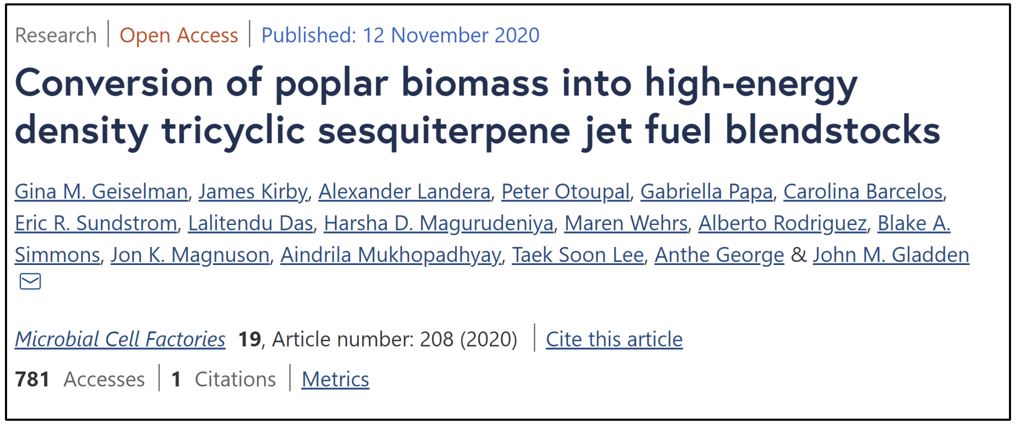
3. Impact

Example 1: we are off-ramping our outcomes to other DOE programs and stakeholders

Connecting to other DOE offices that leverage our project developments

U.S. DEPARTMENT OF ENERGY | Office of Science

JBEI Joint BioEnergy Institute



Research | Open Access | Published: 12 November 2020

Conversion of poplar biomass into high-energy density tricyclic sesquiterpene jet fuel blendstocks

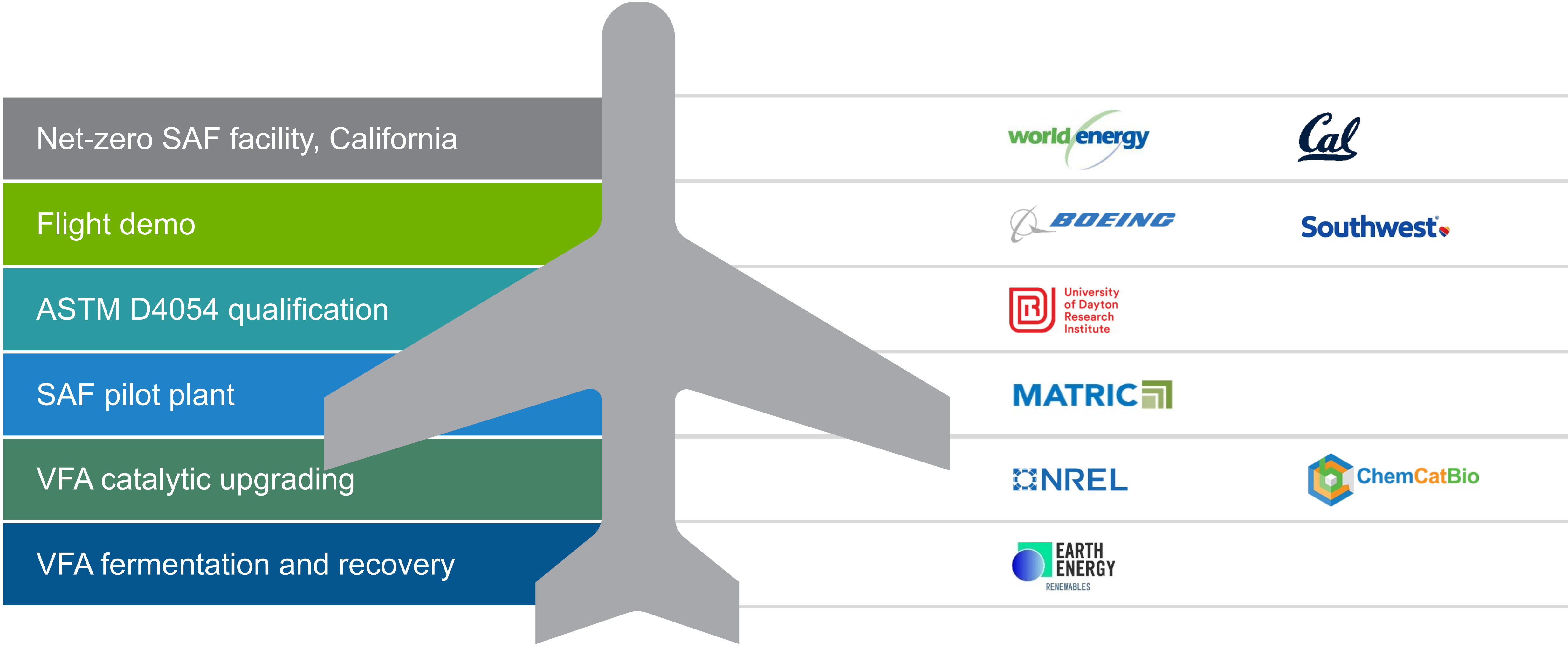
Gina M. Geiselman, James Kirby, Alexander Landera, Peter Otoupal, Gabriella Papa, Carolina Barcelos, Eric R. Sundstrom, Lalitendu Das, Harsha D. Magurudeniya, Maren Wehrs, Alberto Rodriguez, Blake A. Simmons, Jon K. Magnuson, Aindrila Mukhopadhyay, Taek Soon Lee, Anthe George & John M. Gladden

Microbial Cell Factories **19**, Article number: 208 (2020) | Cite this article

781 Accesses | **1** Citations | Metrics

3. Impact

Example 2: we are off-ramping our outcomes to other DOE programs and stakeholders



Net-zero SAF facility, California

Flight demo

ASTM D4054 qualification

SAF pilot plant

VFA catalytic upgrading

VFA fermentation and recovery

- **Off-ramping results to BETO SCUBA FOA with industry for first “waste-to-jet” scale-up**

4. Progress and outcomes

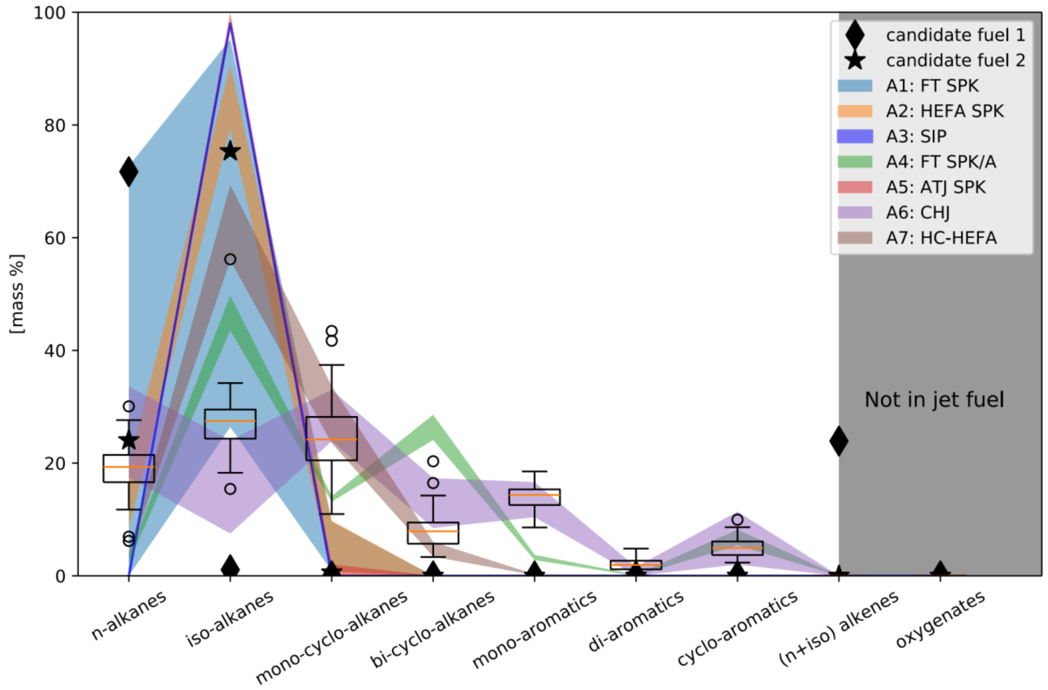
Structure-property and blend work is on track to meet FY21 goals

What molecules and blends are optimal?	How can we reduce SAF production costs?	What is the value proposition to industry?
● Develop structure-property knowledgebase to facilitate improvements in performance while maintaining operational specifications ● Identify promising biologically-derived molecules that increase fuel performance	● Employ low-cost wet-waste feedstocks with conversion chemistry selected for jet-compatibility ● Exploit efficient, tunable ethanol-to-jet conversion technology	● Employ systems modeling at vehicle and fleet level ● Quantify biofuel benefit to meeting CO_2 targets ● Optimize locations of biofuel production for greatest benefit ● Quantify value conferred by increased performance

4. Progress and outcomes

Tier α and Tier β criteria are used to prescreen candidate SAFs

Tier α: GC/GC measurements of fuel composition are analyzed to predict the most likely range of physical property parameters on the basis of a hydrocarbon property database and blending rules



Lead: Heyne, U. Dayton, submitted to FUEL

Tier β: Laboratory measurements compared with Jet-A specifications for important operational parameters

- Viscosity
- Surface tension
- Distillation curve
- Liquid density
- Flash point
- DCN
- Swelling

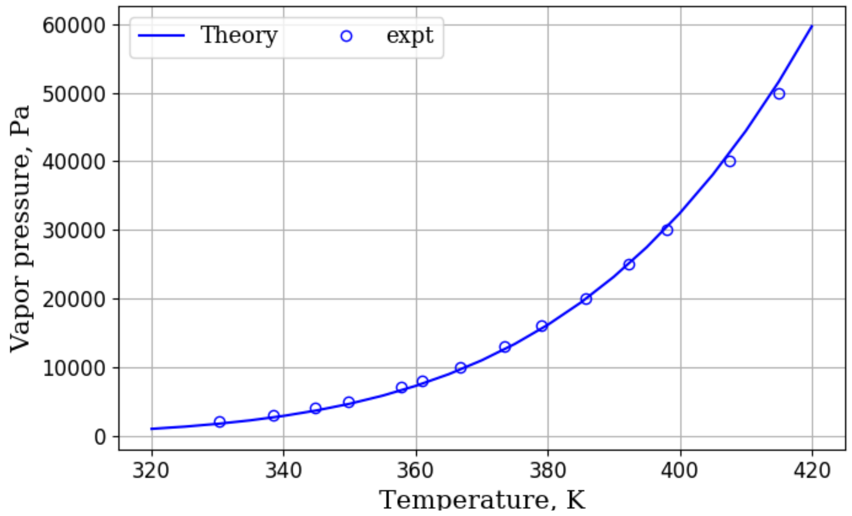
4. Progress and outcomes

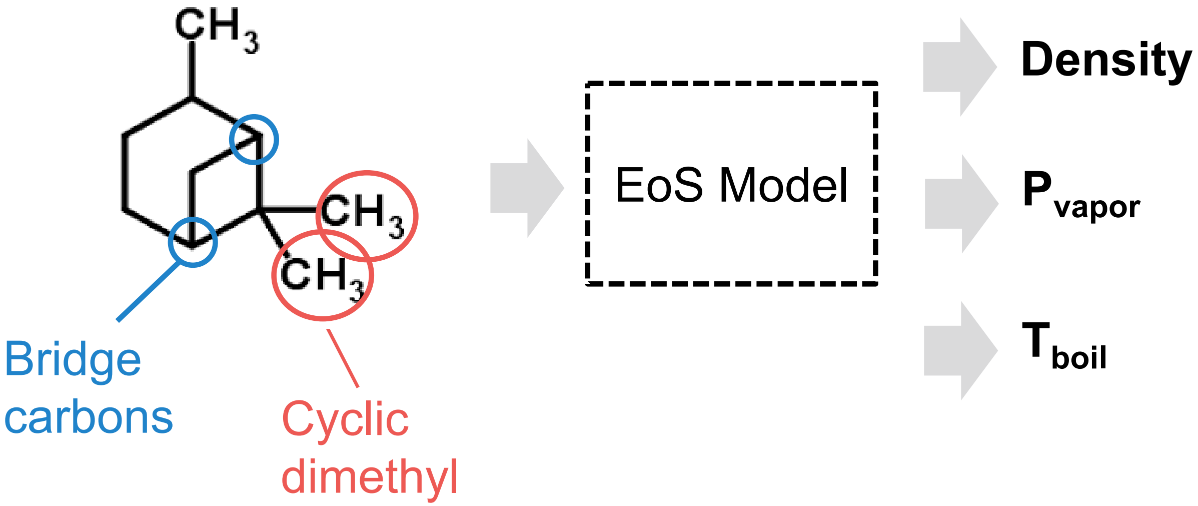
Neat fuels: properties are predicted and structure-function relationships developed

A workhorse for property modeling: Equations of State [EoS]

- Focused on 3 chemical classes and screened >60 fuels
  - Cycloalkanes
  - Branched alkanes
  - Terpenes
- Identified molecules in all families meeting operational specs and conferring performance advantages
- Employed EoS modeling to improve blending rules used in fuel optimization

Lead: George, SNL





Bridge carbons

Cyclic dimethyl

EoS Model

Density

P_{vapor}

T_{boil}

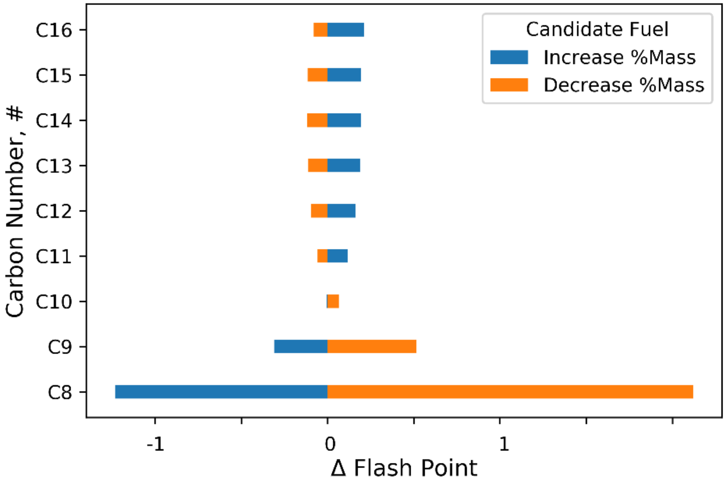
4. Progress and outcomes

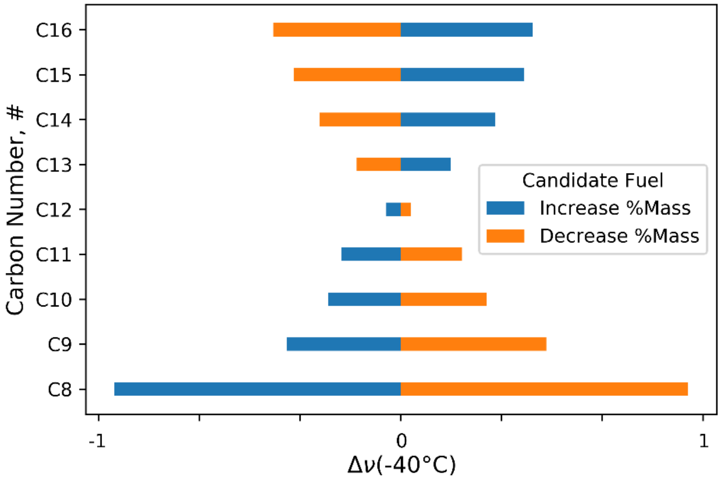
Blended fuels: tools allow blends to be analyzed and optimized to meet specifications

Software tools to evaluate SAF blend components

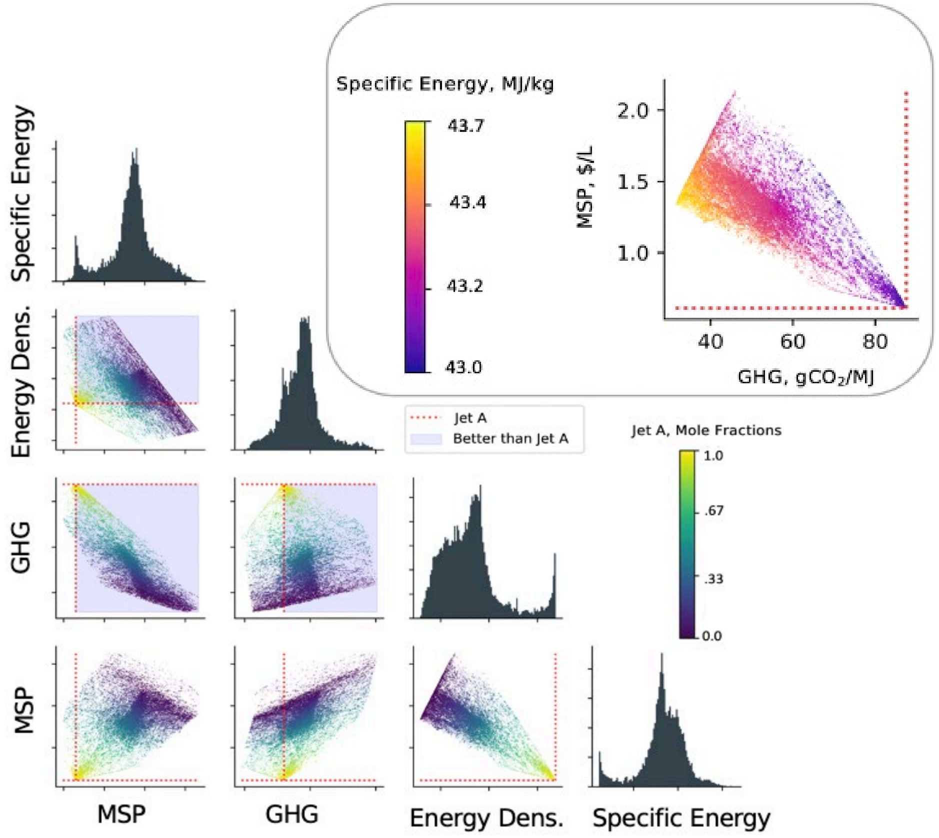
- A best practice for viscosity blend modeling with neat components
- A method for evaluating the sensitivity of operability properties to SAF carbon-number composition
- Four dimensional Pareto to evaluate drop-in SAF candidates on the basis of MSP, GHG, and energy content

Lead: Heyne, U. Dayton





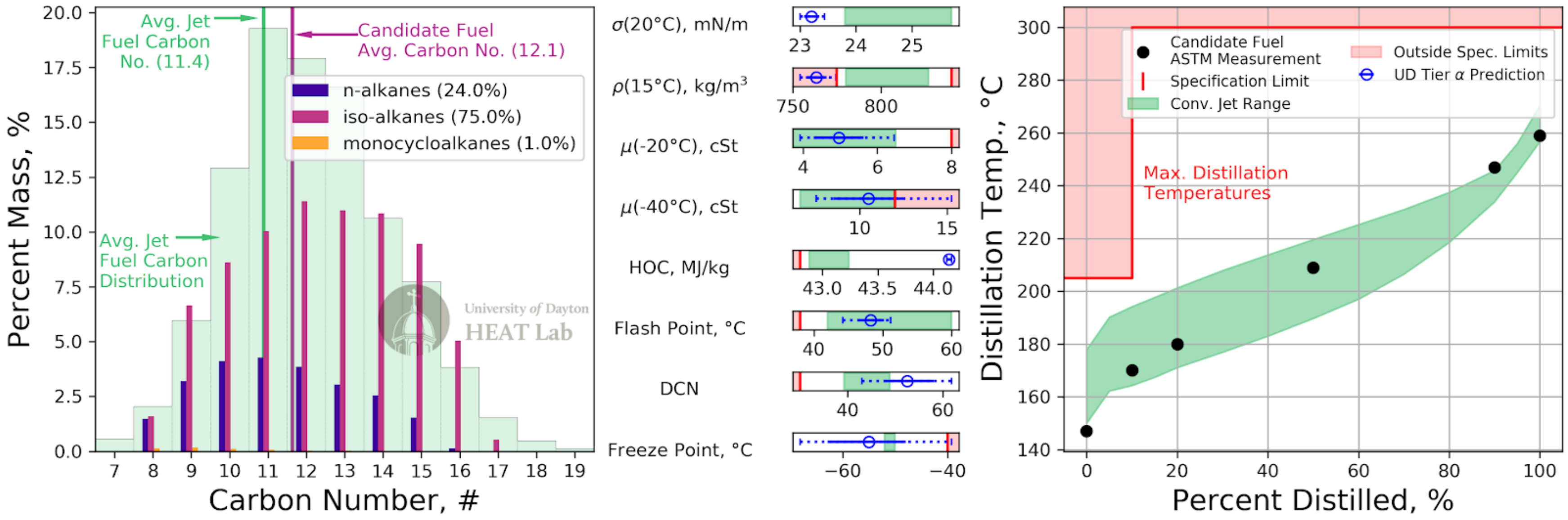
4-D Pareto modelling



4. Progress and outcomes

Prescreening fuels for certification / blend optimization enables rapid “in / out” down-selection

- More than a dozen DOE BETO funded fuels have been evaluated for Tier α and β properties which are critical to the approval and evaluation process (ASTM D4054)
- Panel plots have been sent to labs for all fuels ‘prescreened’



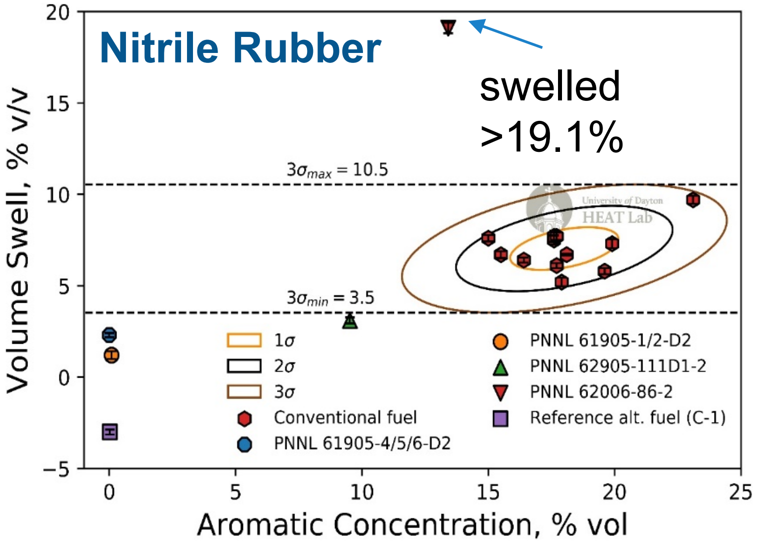
Lead: Heyne, U. Dayton

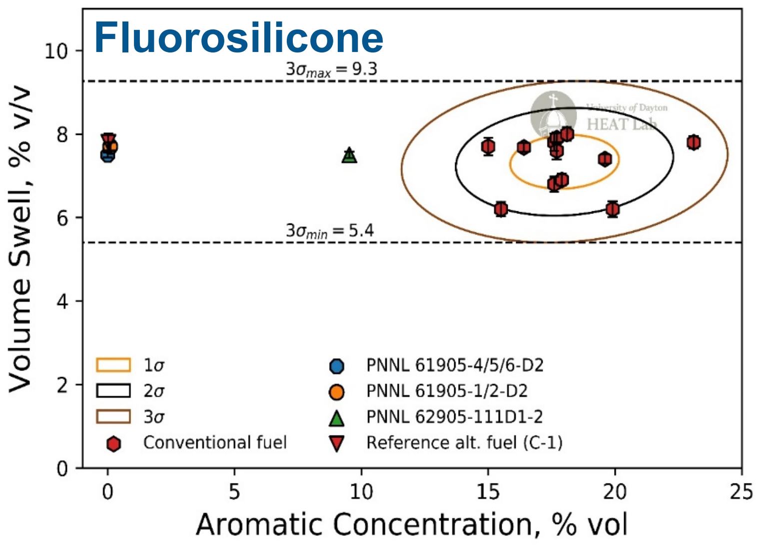
4. Progress and outcomes

SAF seal-swelling evaluated to ensure materials compatability

- PNNL fuels tested with nitrile rubber: none fell within the 3σ range for conventional fuel
- PNNL fuels tested with fluorosilicone: fuels fell within the 3σ range for conventional fuel

Leads: Heyne, U. Dayton; Ramasamy, PNNL



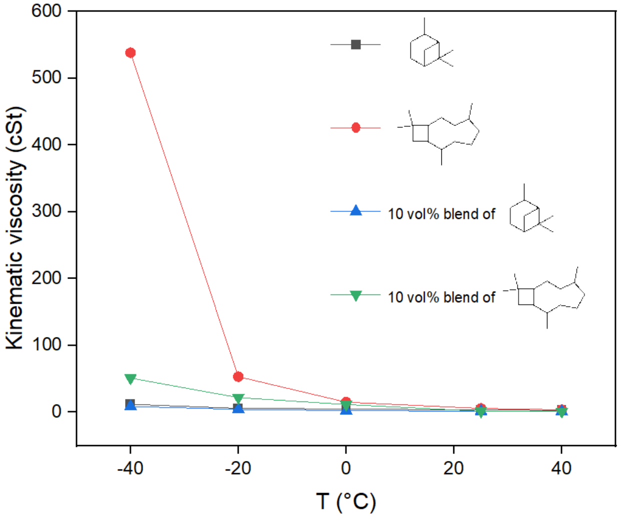


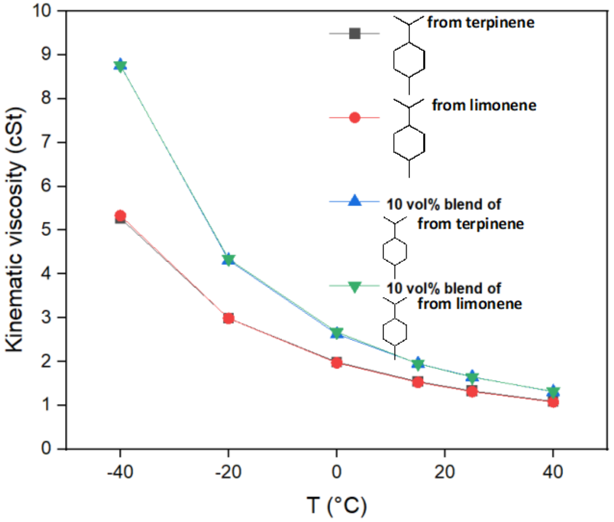
4. Progress and outcomes

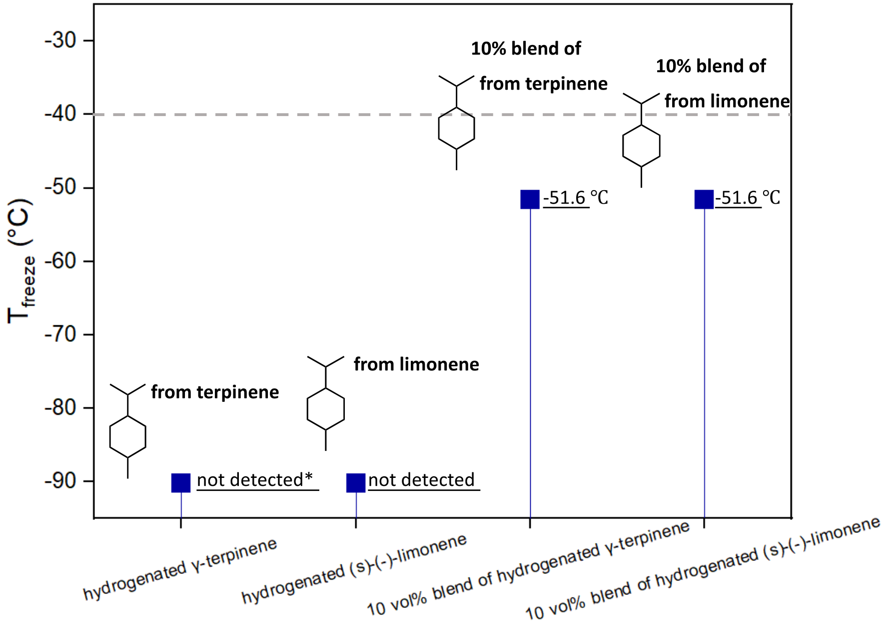
Several terpene candidates were screened for operability parameters

- Hydrogenation was optimized for several terpenes; properties screened on 25-50mL scale
- Fuel property measurements provide validation data for modeling efforts within consortium
  - Multicyclic terpenes tested have poor cold flow properties; monocyclics were acceptable
  - Monocyclic terpenes can have excellent freezing points, much lower than petroleum jet fuel

Lead: Moore, LANL







4. Progress and outcomes

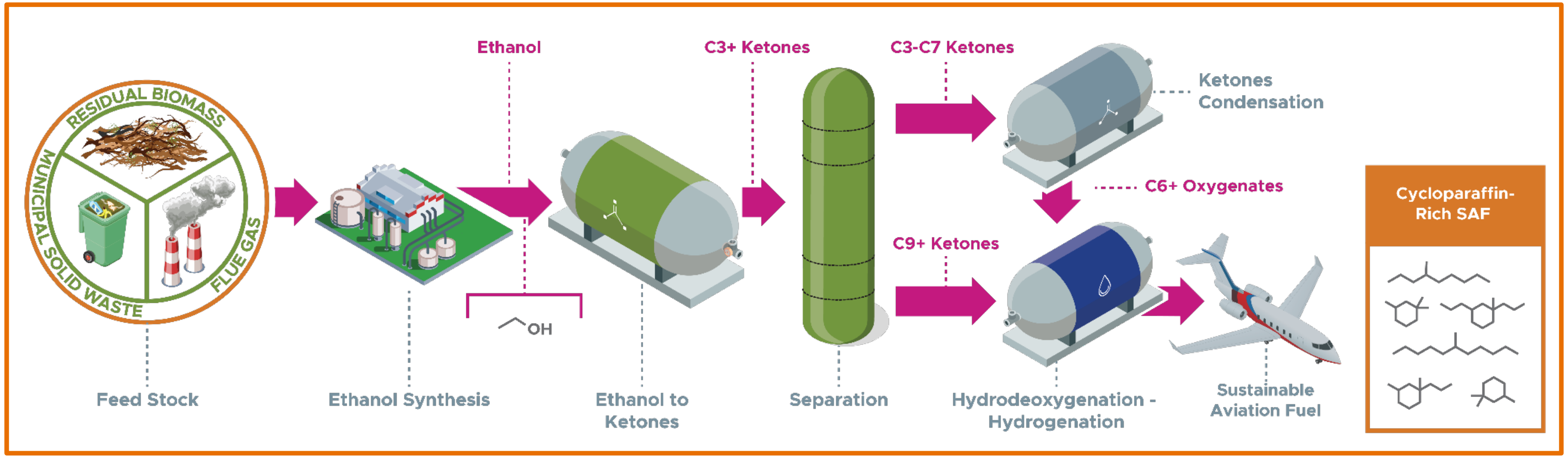
Waste-to-jet conversion work is on track to meet FY21 goals

What molecules and blends are optimal?	How can we reduce SAF production costs?	What is the value proposition to industry?
● Develop structure-property knowledgebase to facilitate improvements in performance while maintaining operational specifications ● Identify promising biologically-derived molecules that increase fuel performance	● Employ low-cost wet-waste feedstocks with conversion chemistry selected for jet-compatibility ● Exploit efficient, tunable ethanol-to-jet conversion technology	● Employ systems modeling at vehicle and fleet level ● Quantify biofuel benefit to meeting CO_2 targets ● Optimize locations of biofuel production for greatest benefit ● Quantify value conferred by increased performance

4. Progress and outcomes

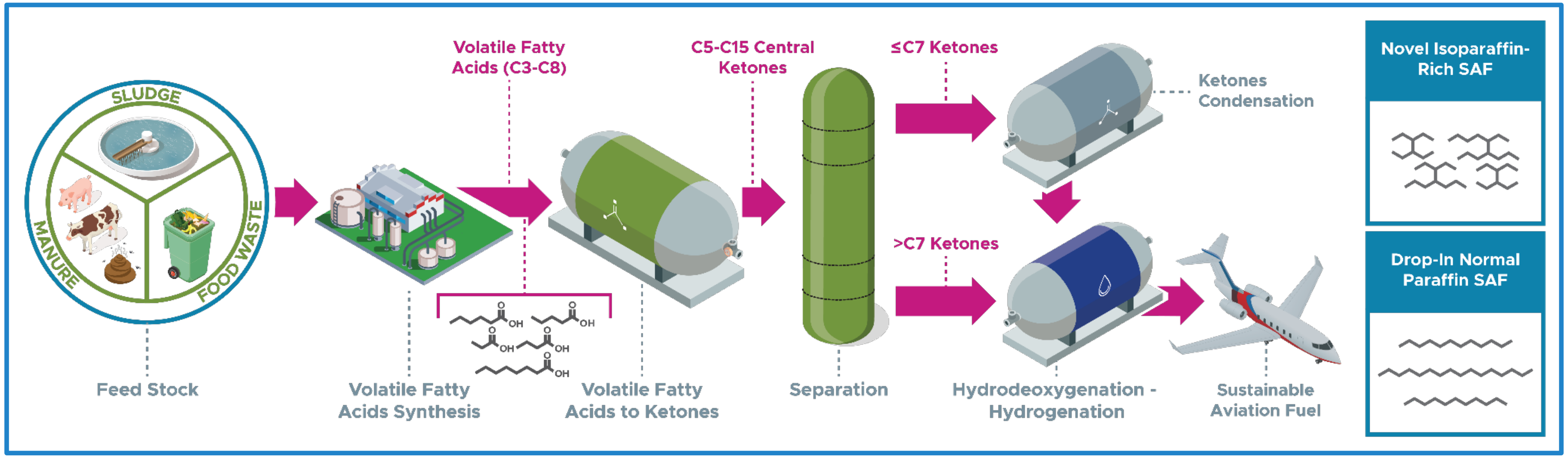
We are pursuing two feedstock approaches for waste-to-jet fuel synthesis

- Waste feedstocks to SAF via ethanol intermediate
- Cycloalkanes and paraffins



RESIDUAL BIOMASS
MUNICIPAL SOLID WASTE
FLUE GAS
Ethanol
C3+ Ketones
C3-C7 Ketones
Ketones Condensation
C6+ Oxygenates
C9+ Ketones
OH
Feed Stock
Ethanol Synthesis
Ethanol to Ketones
Separation
Hydrodeoxygenation - Hydrogenation
Sustainable Aviation Fuel
Cycloparaffin-Rich SAF

- Waste feedstocks to SAF via volatile fatty acid intermediate
- Branched paraffins

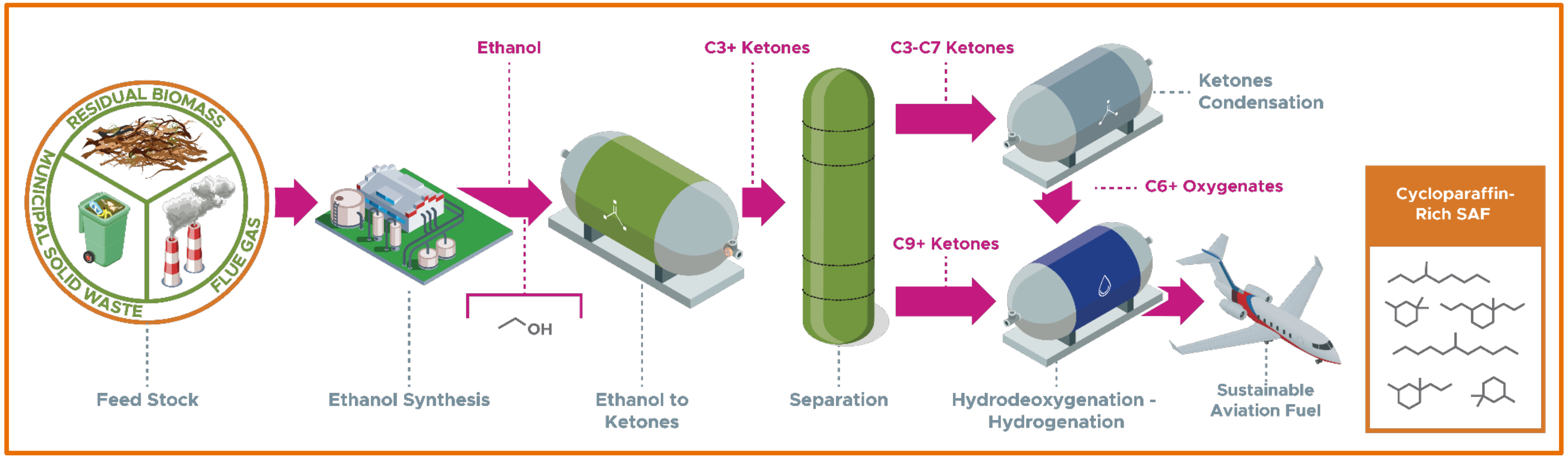


SLUDGE
MANURE
FOOD WASTE
Volatile Fatty Acids (C3-C8)
C5-C15 Central Ketones
≤C7 Ketones
Ketones Condensation
>C7 Ketones
OH
Feed Stock
Volatile Fatty Acids Synthesis
Volatile Fatty Acids to Ketones
Separation
Hydrodeoxygenation - Hydrogenation
Sustainable Aviation Fuel
Novel Isoparaffin-Rich SAF
Drop-In Normal Paraffin SAF

4. Progress and outcomes

Waste derived SAFs from ethanol intermiediate

Goal: to optimize cycloalkane production and product properties and demonstrate the potential fuel costs and GHG savings



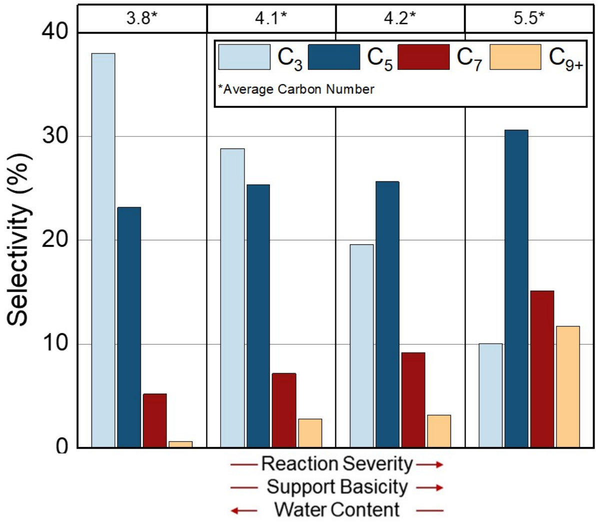
4. Progress and outcomes

Flexibility of ethanol-to-jet catalytic step produces desired jet fuel fraction

- Developed tunable system to produce molecules in target jet range
- Flexible with variable operating conditions (temperature, pressure, feed composition impurities)

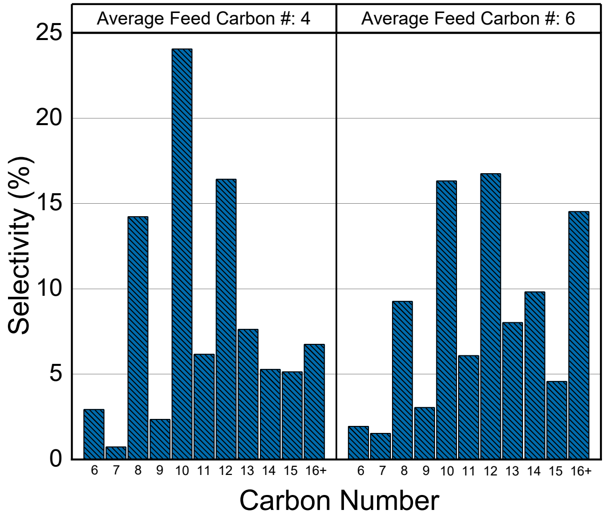
Lead: Ramasamy, PNNL

Ethanol to C3+ Ketones



C3+ Ketones to jet fuel range hydrocarbons

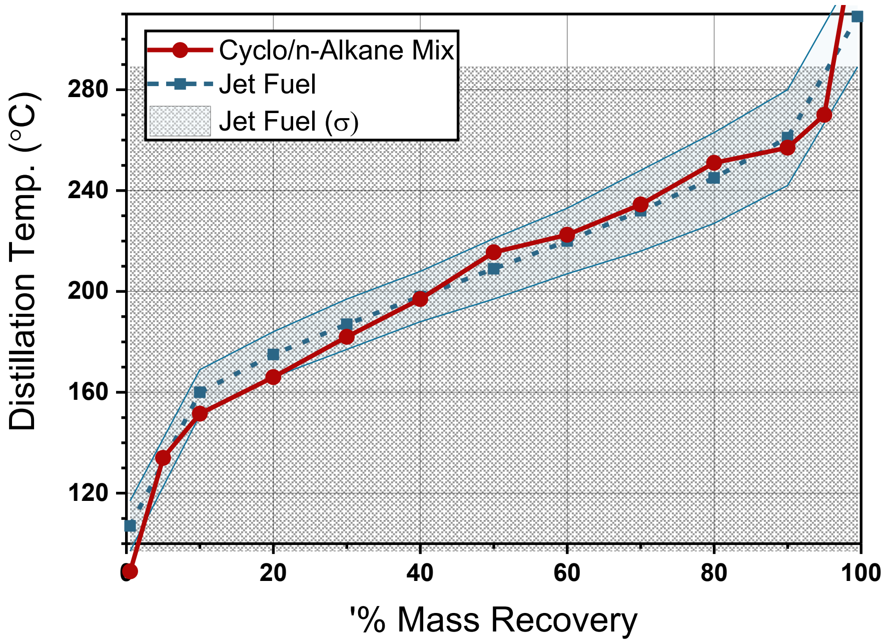
(aldol condensation followed by hydrogenation)



4. Progress and outcomes

Neat and blended ethanol-derived fuel samples meet ASTM requirement

- Cycloalkane/ alkane mixture (neat) simulated distillation curve falls in the conventional jet fuel range
- Fuel properties of the cycloalkane/ alkane mixture was analyzed as neat, 10% & 30% blend in Jet-A
  - Jet-A blended samples at both 10% and 30% levels meet the D7566 requirement
  - Viscosity of the neat sample is outside the range due to the presence of higher carbon number compounds



Sample ID	Viscosity, 40 °C mm²/s	Density, 15 °C g/mL	LHV MJ/kg	Flash Point °C	Freeze Point °C
D7566 (Standard)	Max 12	0.775-0.84	Min 42.8	Min 38	Max -40
PNNL (Neat)	23.2	0.806	43.64	59	< -90
PNNL+ Jet A (10 %)	9.7	0.797	43.15	52	-50.9
PNNL+ Jet A (30 %)	11.0	0.798	43.27	56	-53.4

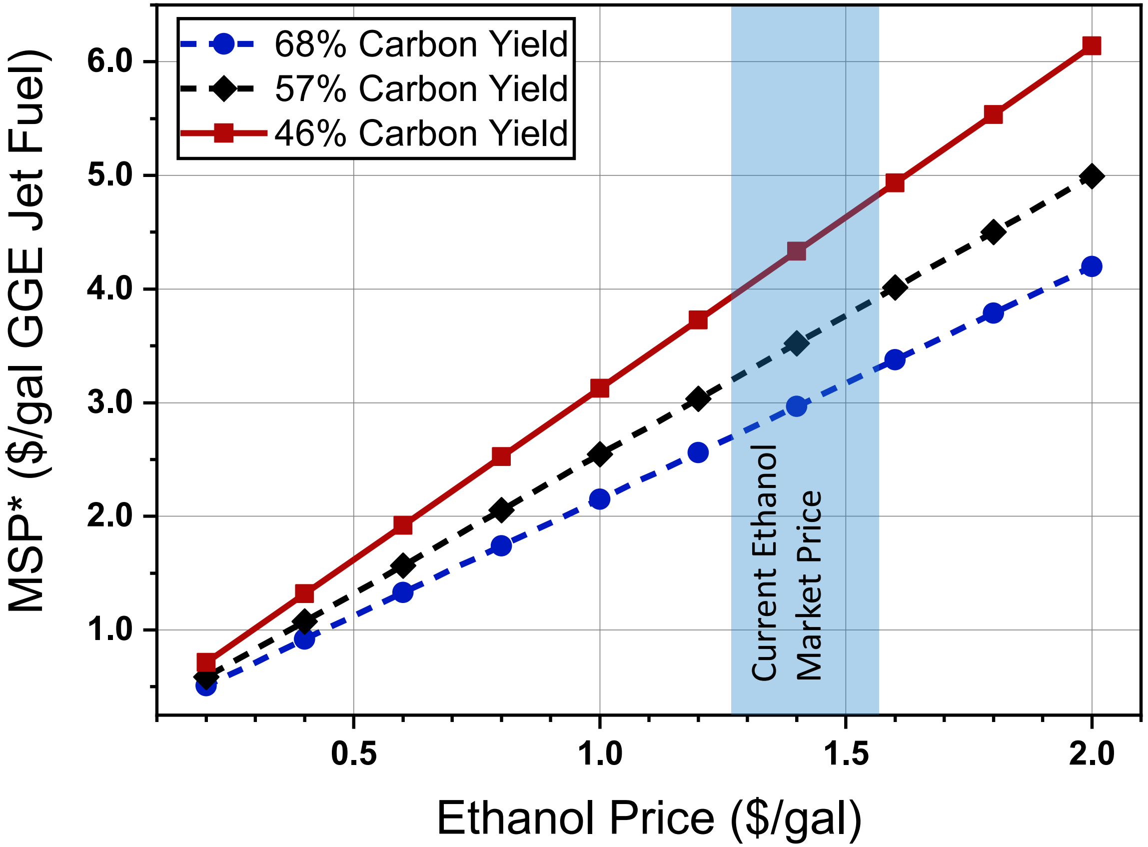
Lead: Ramasamy, PNNL

4. Progress and outcomes

Alcohol feedstock cost is the dominant factor in the final fuel price

- Feedstock cost is the dominant factor in the final fuel price
- Carbon yield level at 46% is based on the current experimental results
- Remaining carbon ends up in naphtha and CO_2
- H_2 generated from ketone formation recycled for the final hydrogenation of products
- Process can potentially be price competitive, particularly if low-cost waste sources are leveraged

Lead: Ramasamy, PNNL



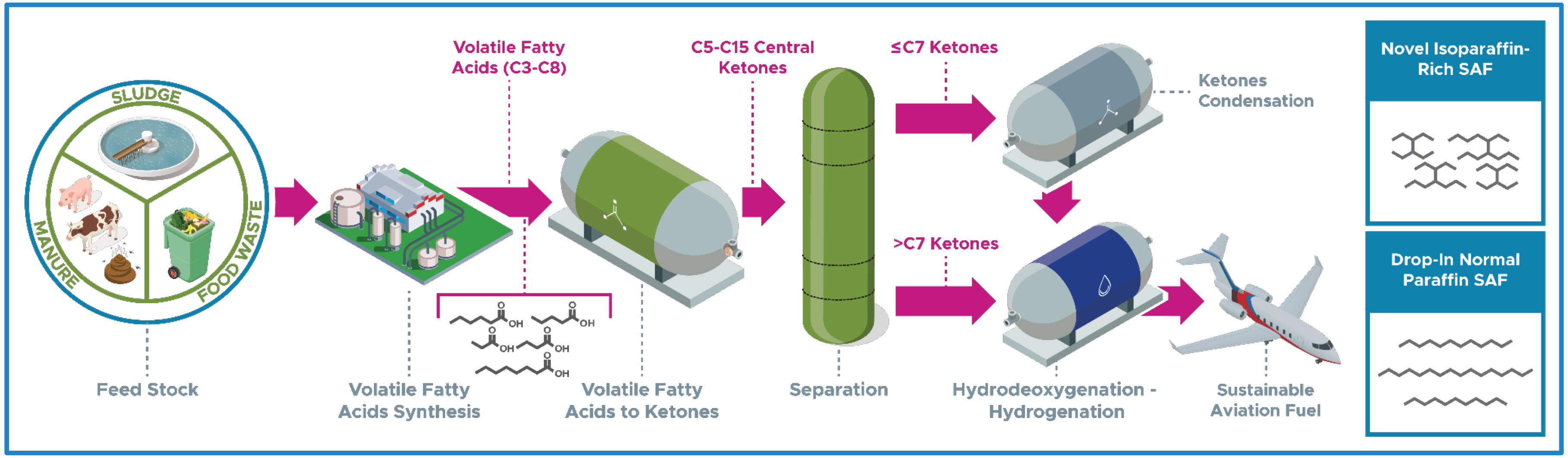
* MSP: Minimum Selling Price

4. Progress and outcomes

Sustainable aviation fuels from wet waste volatile fatty acids

Goal: to de-risk the fuel properties of VFA-SAF to inform conversion R&D and demonstrate the potential fuel costs and GHG savings

Novel 70% VFA-SAF Blend for Net Zero



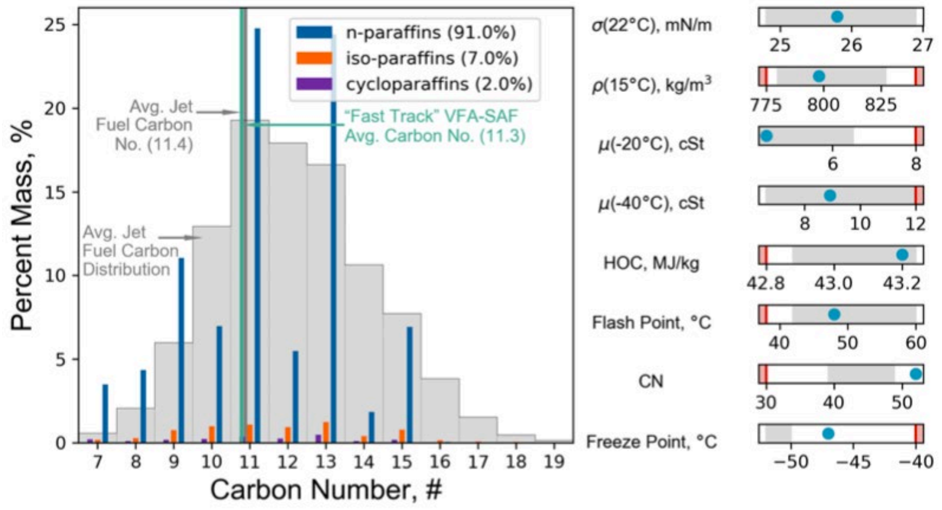
Fast Track VFA-SAF 10% Blend

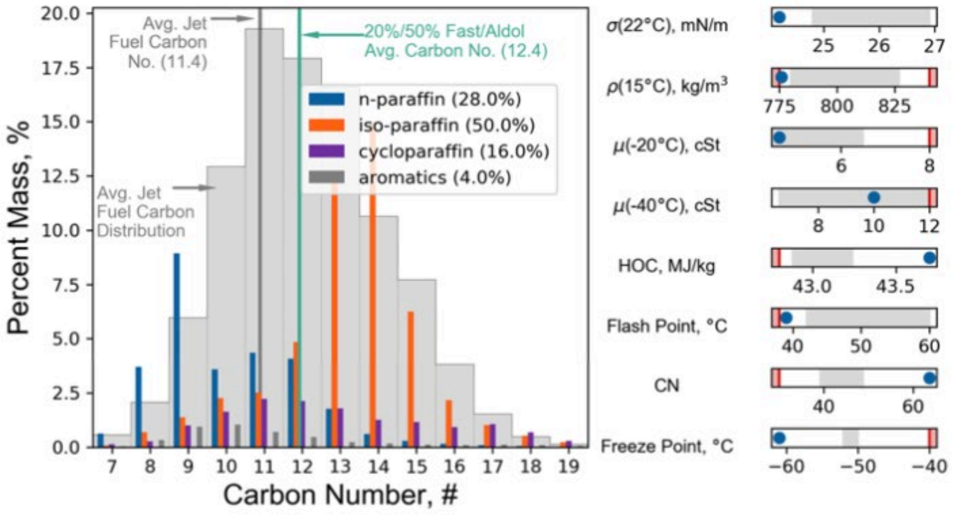
Lead: Vardon, NREL

4. Progress and outcomes

All fuel properties for 10% fast-track blends meet specifications

- Validated 10% Fast Track fuel properties for VFA-SAF normal paraffins, as well as potential for 70% blend with novel VFA-SAF mix
- Fast Track 10% VFA-SAF blend meets ASTM D7566
- Novel 70% VFA-SAF blend meets ASTM D7566





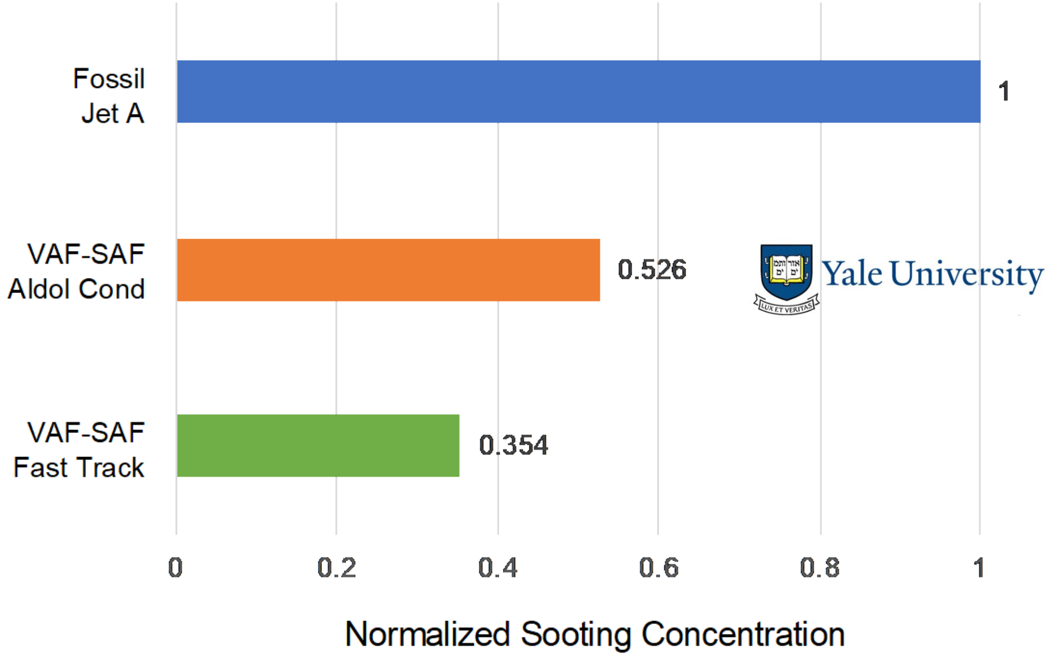
Lead: Vardon, NREL

4. Progress and outcomes

Improved specific energy and sooting properties were demonstrated

Demonstrated exceptionally high specific energy of neat VFA-SAF, as well as significantly reduced sooting

Fuel	POSF	Formula	nHOC, MJ/kg
VFA-SAF Fast Track	N/A	$C_{9.1}H_{20.0}$	**44.5**
VFA-SAF Aldol Cond	N/A	$C_{13.5}H_{28.8}$	**44.1**
Conventional Jet A	10325	$C_{11.4}H_{22.0}$	43.0
Syntroleum FT-SPK	5018	$C_{11.8}H_{25.6}$	44.1
Dynamic Fuels HEFA-SPK	7272	$C_{12.4}H_{26.7}$	43.9
Sasol FT-SPK	7629	$C_{10.8}H_{23.4}$	43.7
UOP HEFA-SPK	10301	$C_{12.0}H_{25.9}$	43.9
Gevo ATJ	11498	$C_{12.6}H_{27.2}$	43.9
Lanzatech ETJ	12756	$C_{11.7}H_{25.4}$	43.9

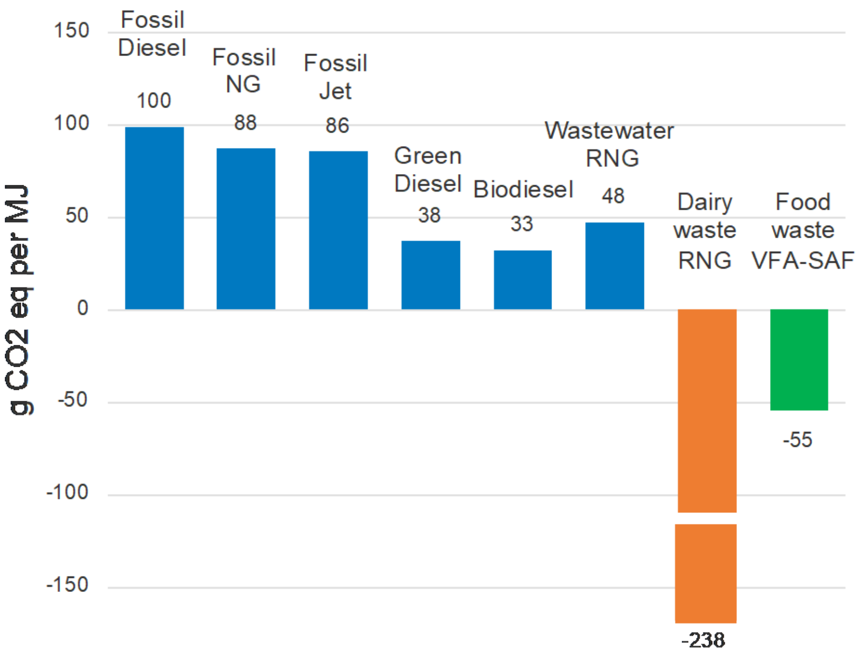


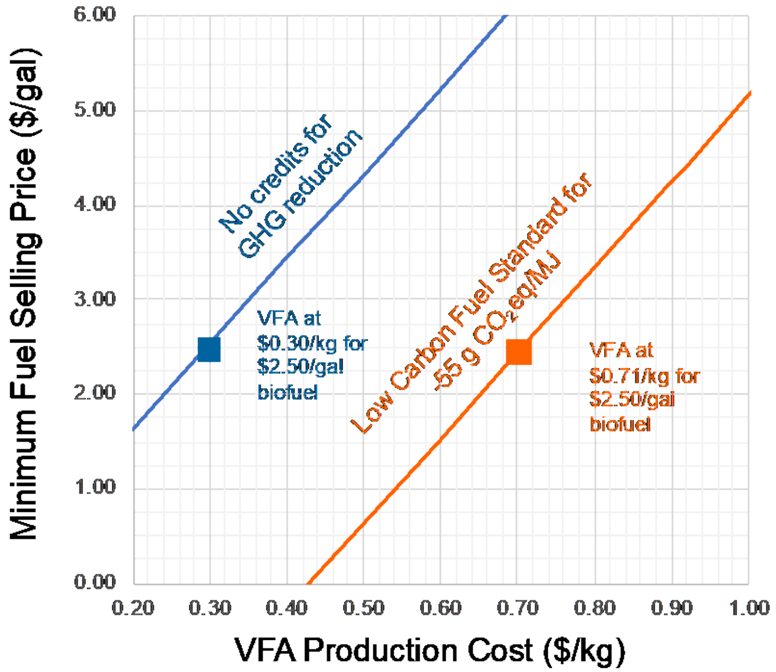
Lead: Vardon, NREL

4. Progress and outcomes

Sustainable aviation fuels from wet waste volatile fatty acids

- Potential for negative life cycle carbon intensity for VFA-SAF derived from waste
- Potential for under $4/gal VFA-SAF without LCFS
- LCFS credit up to $3.70/gal based on GHG





Lead: Vardon, NREL

4. Progress and outcomes

System modeling work is on track to meet FY21 goals

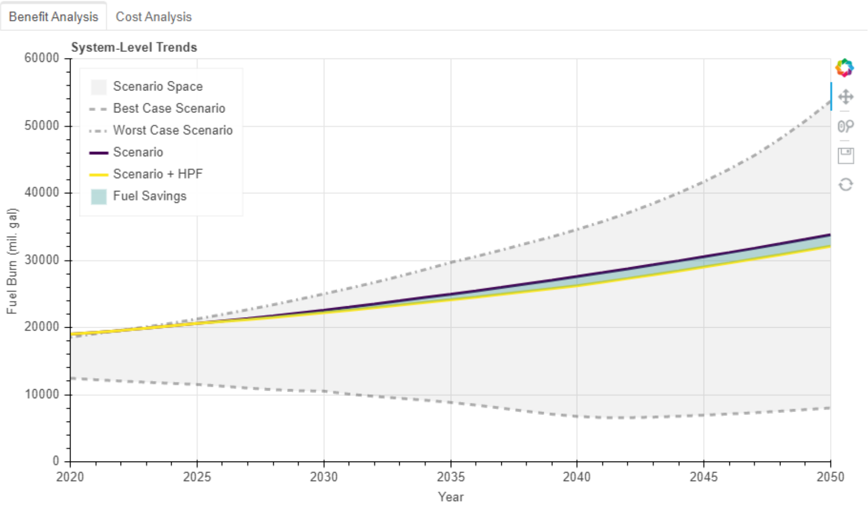
What molecules and blends are optimal?	How can we reduce SAF production costs?	What is the value proposition to industry?
● Develop structure-property knowledgebase to facilitate improvements in performance while maintaining operational specifications ● Identify promising biologically-derived molecules that increase fuel performance	● Employ low-cost wet-waste feedstocks with conversion chemistry selected for jet-compatibility ● Exploit efficient, tunable ethanol-to-jet conversion technology	● Employ systems modeling at vehicle and fleet level ● Quantify biofuel benefit to meeting CO_2 targets ● Optimize locations of biofuel production for greatest benefit ● Quantify value conferred by increased performance

4. Progress and outcomes

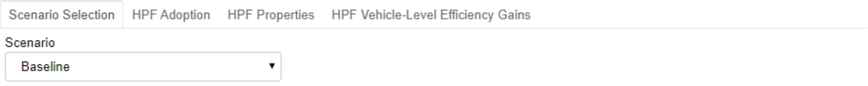
Dashboard provides stakeholders easy visualization of system analyses

Fleet-level analysis

Fuel burn

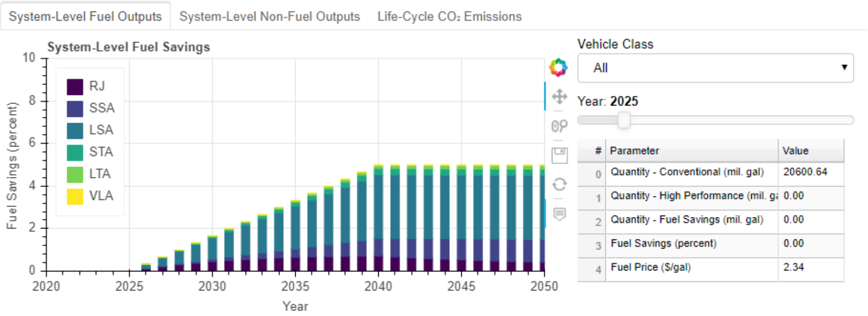


Inputs for SAF scenario



Scenario: Baseline

Fuel savings and monetized benefits

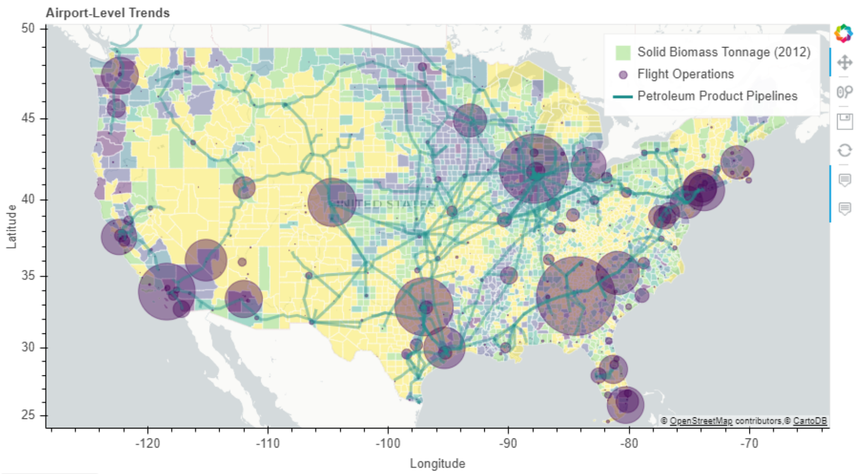


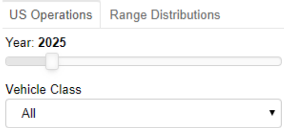
Vehicle Class: All

Year: 2025

#	Parameter	Value
0	Quantity - Conventional (mil. gal)	20600.64
1	Quantity - High Performance (mil. ga	0.00
2	Quantity - Fuel Savings (mil. gal)	0.00
3	Fuel Savings (percent)	0.00
4	Fuel Price ($/gal)	2.34

Airport-level analysis

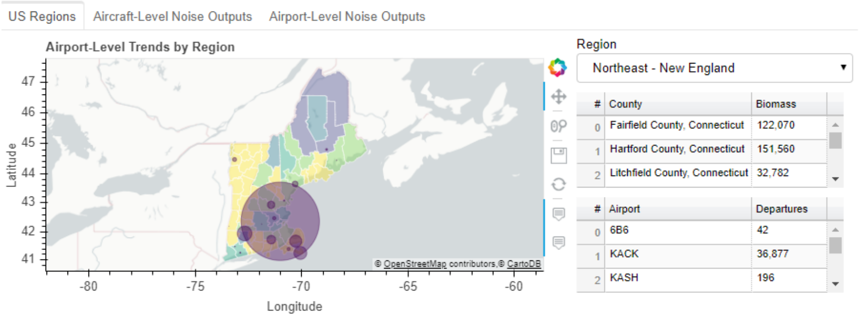




Year: 2025

Vehicle Class: All

Filters for plotting flight operations



Region: Northeast - New England

#	County	Biomass
0	Fairfield County, Connecticut	122,070
1	Hartford County, Connecticut	151,560
2	Litchfield County, Connecticut	32,782

#	Airport	Departures
0	6B6	42
1	KACK	36,877
2	KASH	196

Lead: Kirby, Georgia Tech

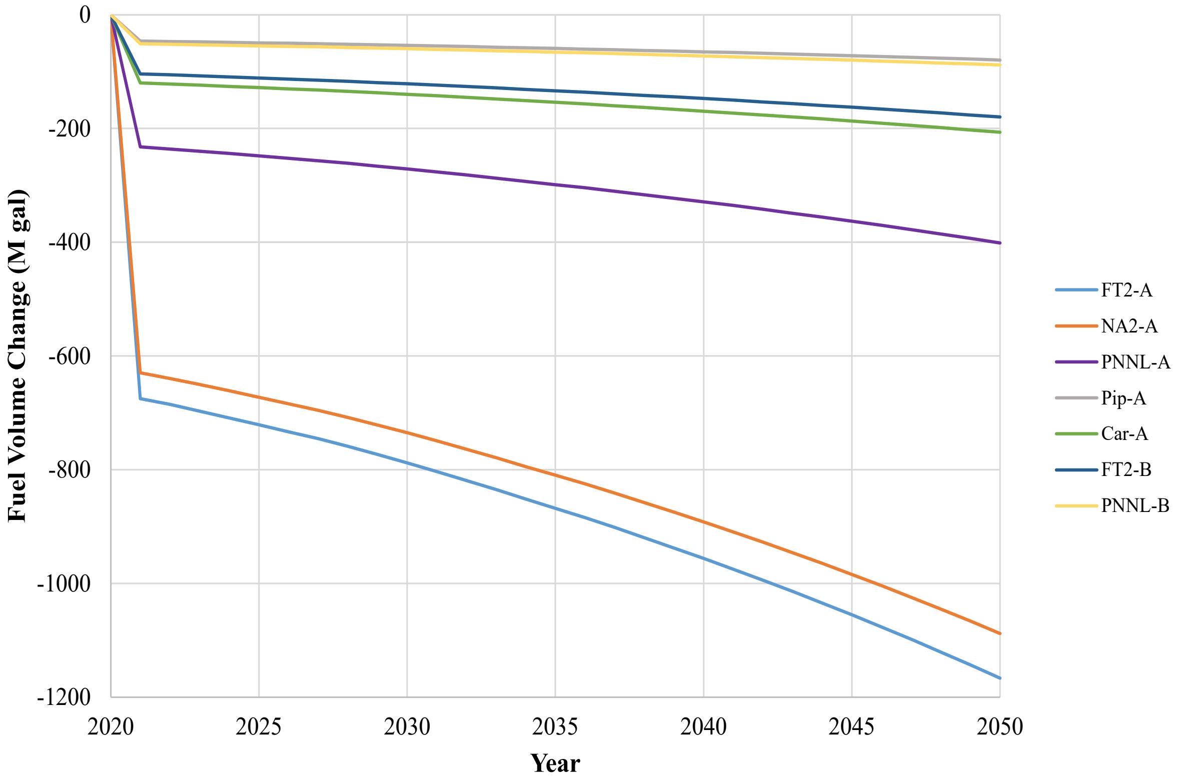
4. Progress and outcomes

Benefits of new biofuels to flight operations are being analyzed

- Six biofuels analyzed; lower and upper bounds of actual fuel energy density identified
- Some fuels show significant performance benefits, >1 billion gallons saved by 2050
- Fuel savings can be significant
  - reduce emissions, noise, operational costs
  - increase payload and/or passengers

Lead: Kirby, Georgia Tech

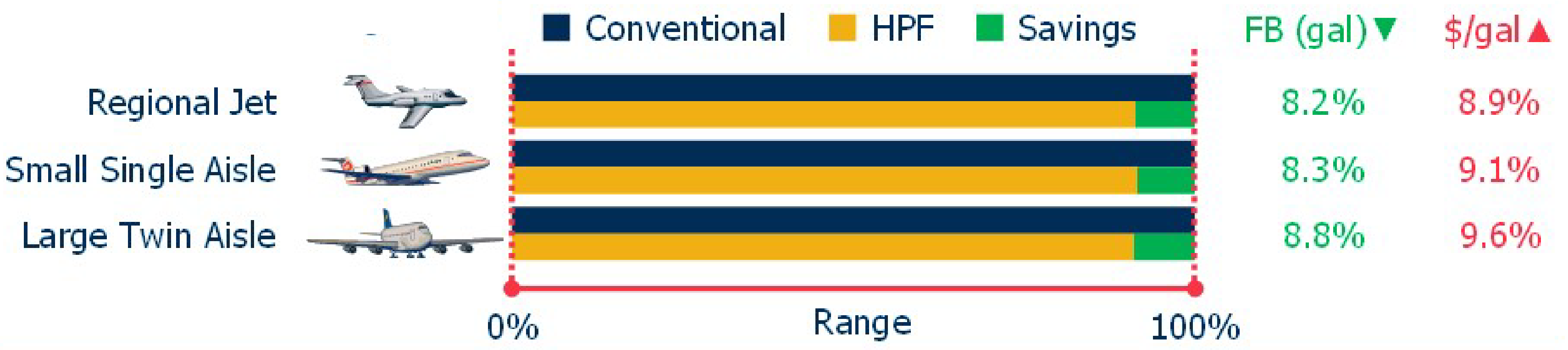
Fleet-level fuel savings



4. Progress and outcomes

Benefits of new biofuels to flight operations show impact of increased energy density

- Increased energy density evaluated for cost savings
- SAF with 3.9% increase in specific energy and 8.6% increase in energy density evaluated
- Largest jet showed greatest fuel savings of 8.8%. Can increase break even fuel price 9.6%



Lead: Kirby, Georgia Tech

Summary

Management, approach, impact, progress and outcomes

Management

- Team of six partners working towards removing roadblocks to SAF deployment
- Strong co-ordination and communication ensure objectives are met
- Risks for technical challenges are identified and mitigated

Approach

- Built models to identify promising SAFs, neat and in blends; conduct screening
- Developed low-cost feedstock routes and analyzed value proposition to industry
- Established metrics and Go/No-go points to ensure progress

Impact

- Advancing technical state-of-the-art and giving stakeholders deployment options
- Off-ramping activities to other DOE programs and stakeholders
- Disseminating technical results in high impact publications

Progress & outcomes

- Models developed and > 60 fuels screened for operation and performance properties
- Two low-cost production routes to cycloalkanes / paraffins can be tuned for properties
- Fleet-level analysis determined fuel savings with improved energy density

Quad chart overview

Timeline

- Year 1: October 1, 2019 to September 30, 2020
- Year 2: October 1, 2020 to September 30, 2021
- Year 3: October 1, 2021 to September 30, 2022

	FY20	Active Project
DOE funding	LANL, NREL, PNNL, SNL, UDayton, GTech $250k each partner	$1250 / yr

Partner labs

- LANL, NREL, PNNL, SNL, UDayton, Georgia Tech

Barriers addressed:

ADO-H Materials Compatibility, and Equipment Design and Optimization

At-A Analysis to Inform Strategic Direction

Ft-A Feedstock Availability and Cost

Ot-B Cost of Production

Project goal

- Address key roadblocks to deploying new sustainable aviation fuels

End-of-project milestones

- Identify the technical targets and projected production capacity of at least one waste-to-biojet pathway in line with the DOE cost targets of $2.50/GGE by 2030
- Quantify the potential impact of optimized biojet fuel blend production to the airline industry based on supply chain constraints

Funding

- Annual operating plan

Additional slides

Acronyms and Symbols

ACS	American Chemical Society
ATJ	Alcohol-to-jet
CRC	Coordinating Research Council
DCN	Derived cetane number
ETJ	Ethanol-to-jet
EoS	Equation of State
FAA	Federal Aviation Administration
FT-SPK	Fischer-Tropsch Synthetic Paraffinic Kerosene
GC/GC	Two dimensional gas chromatography
GGE	Gallons gasoline equivalent
GHG	Greenhouse gas
HDO	Hydrodeoxygenation
HEFA	Hydroprocessed Esters and Fatty Acids
HTL	Hydrothermal liquefaction
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
LCA	Lifecycle analysis
MESP	Minimum ethanol selling price
MSP	Minimum selling price
PNAS	Proceedings of the National Academy of Sciences
SAF	Sustainable aviation fuel
TEA	Techno-economic analysis / lifecycle analysis
VFA	Volatile fatty acid
YSI	Yield sooting index

$\boldsymbol{\nu}$	viscosity
$\boldsymbol{\mu}$	kinematic viscosity
$\boldsymbol{\sigma}$	surface tension or standard deviation
$\boldsymbol{\rho}$	density

Papers, Presentations, Patents

Peer Reviewed Publications

Feldhausen, J. J., Bell, D. C., Kosir, S. T., Heyne, J. S., Scown, C., Rapp, V., and Comesana, A. The Co-Optimization of Sustainable Aviation Fuel: Cost, Emissions, and Performance. AIAA SciTech, Jan. 2021

Geiselman, G.M, et al., Conversion of poplar biomass into high-energy density tricyclic sesquiterpene jet fuel blendstocks. Microbial Cell Factories (2020) https://doi.org/10.1186/s12934-020-01456-4

Hauck F, Kosir S, Yang Z, Heyne J, Landera A, George A. Experimental validation of viscosity blending rules and extrapolation for sustainable aviation fuel. AIAA Propulsion and Energy 2020 Forum 2020:1–15. https://doi.org/10.2514/6.2020-3671.

Hauck F, Kosir S, Yang Z, Heyne J, Landera A, George A. Experimental validation of viscosity blending rules and extrapolation for sustainable aviation fuel. AIAA Propulsion and Energy 2020 Forum 2020:1–15. https://doi.org/10.2514/6.2020-3671.

Huq, N.A. ,G.R. Hafenstine, X. Huo, H. Nguyen, S.M. Tifft, D.R. Conklin, D. Stück, J. Stunkel, Z. Yang, J.S. Heyne, M.R. Wiatrowski, Y. Zhang, L. Tao, J. Zhu, C.S. McEnally, E.D. Christensen, XC. Hays, K.M. Van Allsburg, K.A. Unocic, H.M. Meyer III, X. Abdullah, D.R. Vardon. 2020). Towards Net-Zero Sustainable Aviation Fuel with Wet Waste-Derived Volatile Fatty Acids. Proceedings of the National Academy of Science (Accepted, awaiting DOI)

<u>In review</u>: Zhibin Yang, Shane Kosir, Robert Stachler, Linda Shafer, Carlie Anderson, Joshua S. Heyne, "A GCxGC Tier α Combustor Operability Prescreening Method for Sustainable Aviation Fuel Candidates," currently under review by Fuel

Papers, Presentations, Patents

Patent Applications

D.R. Vardon, X. Huo, N.A. Huq. H. Nguyen. Fuels and Methods of Making the Same. U.S. non-provisional patent application No. 17/121,336 filed on December 14, 2020.

Mond Guo, Senthil Subramaniam, Abraham Martinez, Karthikeyan Ramasamy Processes for the Conversion of Mixed Oxygenates Feedstocks to Hydrocarbon Fuels

Conference Presentations

D.R. Vardon, N.A. Huq, G.R. Hafenstine, X. Huo, D.R. Conklin, D. Stuck, H. Nguyen, S.M. Tifft, J. Stunkel, E. Christensen, G. Fioroni, M.R. Wiatrowski, Y. Zhang, L. Tao, X. Abdullah. Wet Waste for Sustainable Aviation Fuel. International Congress on Sustainability Science Engineering, Virtual. August 2020.

D.R. Vardon, N.A. Huq, G.R. Hafenstine, X. Huo, D.R. Conklin, D. Stuck, S.M. Tifft, J. Stunkel, E. Christensen, G.M. Fioroni, M.R. Wiatrowski, Y. Zhang, L. Tao, Z. Abdullah. Decarbonizing Aviation Fuels with Wet Waste Volatile Fatty Acids. Fall 2020 American Chemical Society Meeting, Virtual. August 2020.

Heyne J., High Value Drop-in Aviation Fuels: From Molecule Selection to Mission Benets, Panel Title: Fuel quality matters, DOE BETO/ PNNL HTL Workshop, virtual, November 2020.

Heyne J., Prescreening of HTL SAFs: Rapid low-volume, lowcost testing, Panel Title: Sustainable Aviation Fuel Certication, DOE BETO/ PNNL HTL Workshop, virtual, November 2020.

Papers, Presentations, Patents

Conference Presentations

Gabrielian, A., “Survey on Aviation Biofuels Infrastructure and Distribution from an Airport Perspective,” 2021 AIAA SciTech Forum, DOI: 10.2514/6.2021-1810, January 2021.

Hauck, F., Prescreening Sustainable Aviation Fuel Candidates,” University Board of Trustees, January 2021.

Hassan, M., System-Level Assessment of High Performance Fuels in Aviation, 2020 AIAA AVIATION Forum, DOI: 10.2514/6.2020-2875, June 2020.

Heyne J., Routes to sustainable aviation fuels, Energy and Fuels (ENFL) Division, ACS Fall 2020 National Meeting & Exposition, virtual, August 2020.

Heyne J., Overview of the Opportunities in Biojet BETO Program, Federal Alternative Jet Fuel Strategy Working Group, Webinar, June 2020.

Heyne J., “Optimization of Drop-in Sustainable Aviation Fuels," Institute Lecture, DLR Germany, Stuttgart, DE, December 2019, Sponsored Travel.

Heyne J., “SAF Benets Beyond CO2 Reduction," Sustainable Fuels for Aviation in Europe, EU Commission, Press Club Brussels, Brussels, BE, November 2019, Sponsored Travel.

Heyne ,J., Shane Kosir, Robert Stachler, Franchesca Hauck, Lily Behnke, Giacomo Flora, “Value Optimized Drop-in Sustainable Aviation Fuels,” Maximizing sustainable aviation fuel benefits beyond CO2 reduction, Policy Maker Workshop, Press Club, Brussels, Belgium, November 2019.

Papers, Presentations, Patents

Conference Presentations

Landera, R.P. Bambha, A. George, Predicting physical properties of bio-renewable of molecules in a search for a drop-in Jet-A fuel, Energy and Fuels (ENFL) Division, ACS Fall 2019 National Meeting & Exposition, San Diego, CA

Mond Guo, Senthil Subramaniam, Abraham Martinez, Steven Phillips, Michael Thorson, Karthikeyan Ramasamy; Waste Streams to Sustainable Aviation Fuel: Cycloalkanes Rich Fuel from Ethanol, TCS 2020, Richland, WA