Alternative jet fuel supply chain analysis

Massachusetts Institute of Technology & UHasselt (subaward)

PI: S. Barrett, R. Malina, F. Allroggen

PMs: *Dan Williams, Nate Brown, Jim Hileman*

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 1 through FAA Award Number 13-C-AJFE-MIT under the supervision of Dan Williams, Nate Brown and Jim Hileman. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 1

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Analyze lifecycle GHG emissions, costs, and availability of Sustainable Aviation Fuels, considering a wide range of production pathways and feedstocks. Research is conducted in support of efforts under ICAO CAEP.

Focus topic today: Future availability of SAF out to 2050

Project Benefits *(focus topic)* **:**

1. Detailed outline of potential SAF uptake scenarios over the coming decades
2. Analysis of future GHG reduction potential from SAF

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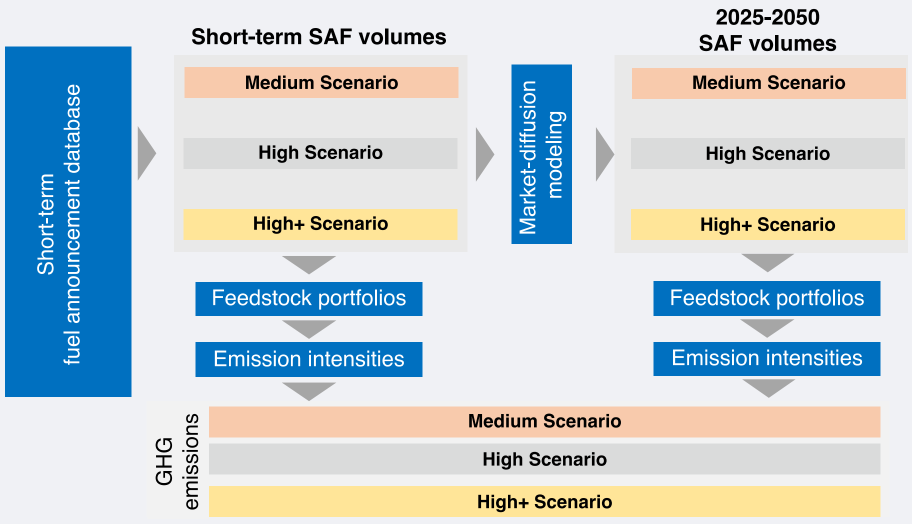
Research Approach *(focus topic)* :



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Research approach (1 of 3)

Short-term SAF scenarios

Short-term
fuel announcement database

Some SAF policy support ("medium" scenario)

- Only relatively mature production plans
- High failure rate of plans
- Low jet production share in product slate

Level Playing Field policies ("high" scenario)

- Some immature plans considered, as well
- Medium failure rate of plans
- Higher jet production share in product slate

SAF-emphasis policies ("high+" scenario)

- Many immature plans considered, as well
- Low failure rate of plans
- High jet production share in product slate
- Shift from renewable diesel to SAF production

Research approach (2 of 3)

Short-term SAF volumes

- Medium Scenario
- High Scenario
- High+ Scenario

Market-diffusion modeling

2025-2050 SAF volumes

- Medium Scenario
- High Scenario
- High+ Scenario

Model	Description	Functional form	Variables[b]
Models dependent on a exogenous asymptote[a]			
Logistic	Genuine S-shaped curve, symmetric, and with a point of inflection at $0.5S$	$y(t) = \frac{S}{1 + a \cdot b^{(-c \cdot t)}}$	• $y(t)$, demand for SAF by year t • S, exogenous asymptote • a, b, c, constants
Gompertz	Simple mathematical function that depicts an asymmetric S-shaped curve	$y(t) = S \cdot e^{-a \cdot e^{-b \cdot t}}$	
Blackman	This model assumes that the environment of the diffusion is unchanged	$y(t) = S \cdot \left[\frac{e^{a+b \cdot t}}{1 + e^{a+b \cdot t}}\right]$	
Sharif-Kabir	Known as a flexible technology replacement model that involves the delay of the adoption compared to optimistic approaches	$ln\left(\frac{y}{S-y}\right) + \frac{a \cdot S}{S-y} = b + c \cdot t$	
Model with an endogenous asymptote			
Logistic model 2	Variation of the original logistic model to include the initial demand for SAF	$y(t) = \frac{a \cdot y_0}{b \cdot y_0 + (a - b \cdot y_0) \cdot e^{-a \cdot t}}$	• $y(t)$, demand for SAF by year t • y_0, initial demand for SAF • a, b, c, constants • S^*, endogenous asymptote
Gompertz 2	Variation of the Gompertz model to include the initial demand for SAF	$y(t) = e^{\frac{e^{-b \cdot t} \cdot [b \cdot ln(y_0) - a] + a}{b}}$	
Sharif-Kabir 2	Variation of the Sharif-Kabir model but treating S^* as an unknown parameter	$ln\left(\frac{y}{S^*-y}\right) + \frac{a \cdot S^*}{S^*-y} = b + c \cdot t$	

Research approach (3 of 3)

Short-term SAF volumes

- Medium Scenario
- High Scenario
- High+ Scenario

Market-diffusion modeling

2025-2050 SAF volumes

- Medium Scenario
- High Scenario
- High+ Scenario

Feedstock portfolios

Emission intensities

Feedstock portfolios

Emission intensities

GHG emissions

- Medium Scenario
- High Scenario
- High+ Scenario

Results (1 of 3): Short-term

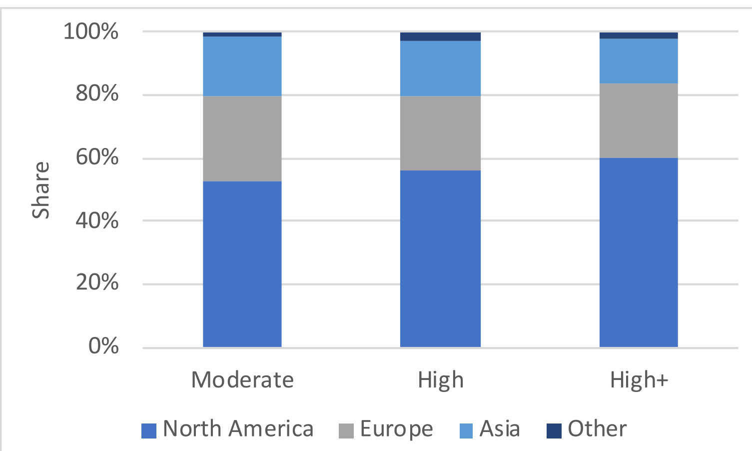
Short-term SAF production (in kt)

Year	Moderate (Some SAF policy)	High (Level Playing Field)	High+ (SAF-Emphasis)
2021	574.45	2700.65	4403.17
2022	955.34	3967.40	6264.74
2023	1271.02	5093.58	7327.57
2024	1764.42	6410.96	9138.80
2025	1824.86	6619.27	9332.53

Short-term technology split

ASTM specification	Moderate	High	High+
FT-SPK	11.48%	8.94%	5.64%
HEFA-SPK	82.91%	86.53%	90.84%
HFS-SIP	0.00%	0.15%	0.21%
ATJ-SPK	1.17%	1.21%	0.97%
CH-SK	2.67%	1.59%	1.21%
Lipid coprocessing	1.23%	1.59%	1.13%

Regional split

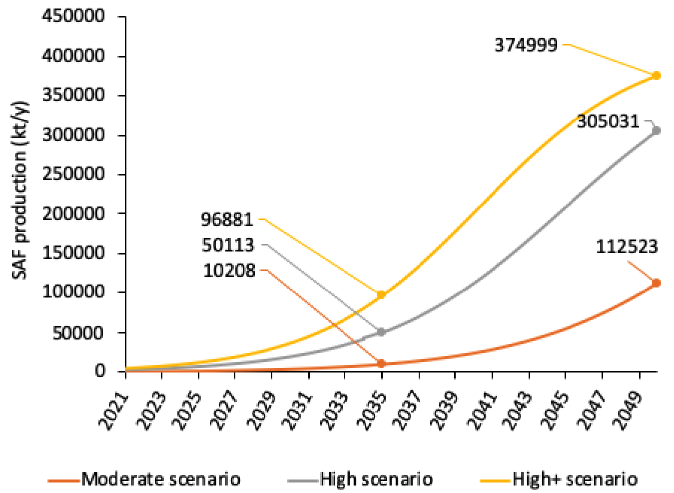


Split by type of production plan

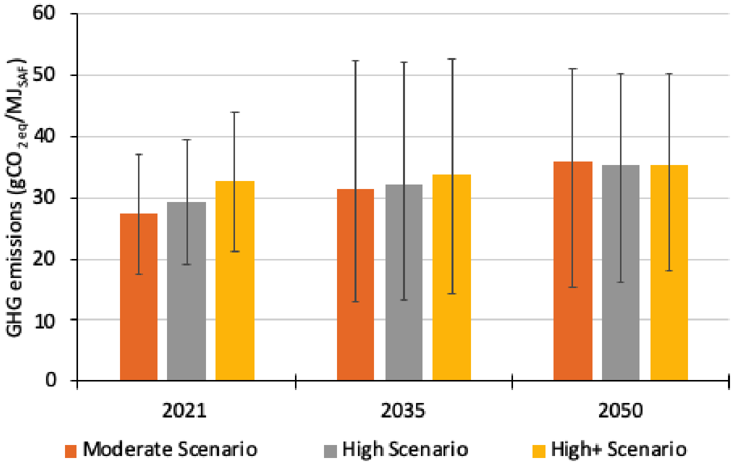
Scenario	Share by type of Facility		
	Specified SAF-ambition (or actual production)	Unspecific SAF ambition	No announced SAF plans but pathway can produce SAF
Moderate	61%	39%	0%
High	37%	44%	20%
High+	36%	32%	33%

Results (2 of 3): Out to 2050

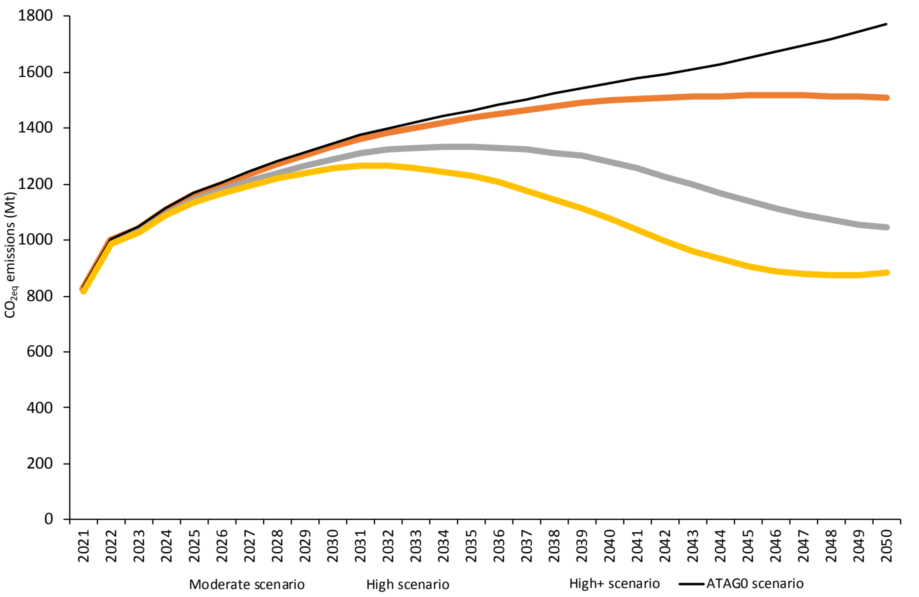
SAF usage, by scenario



GHG intensity per unit SAF



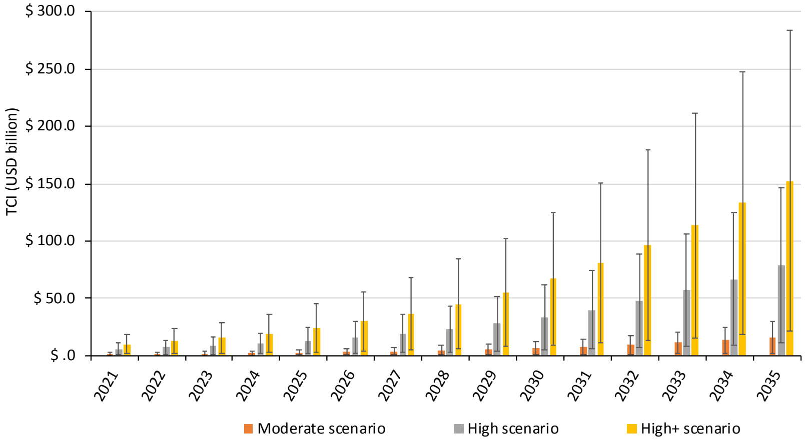
CO2e commercial aviation, by scenario, compared to 100% conventional jet fuel usage



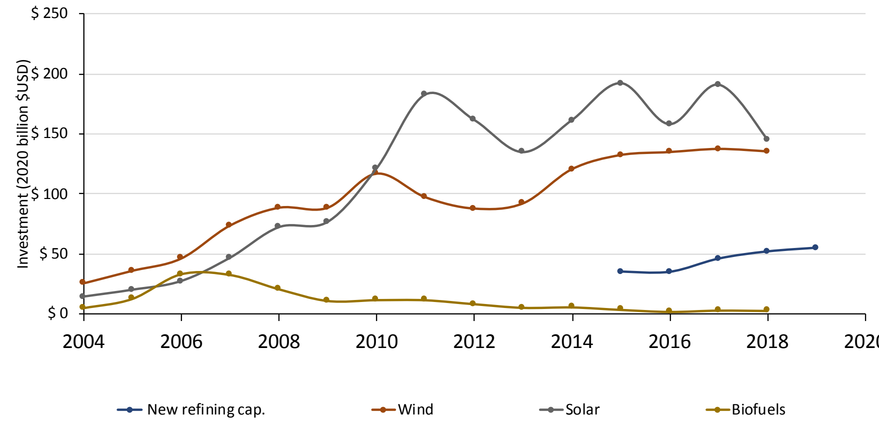
Colored areas show range of emissions per scenario, solid lines indicate mid-point estimate for each scenario

Results (3 of 3): Interpretive metrics

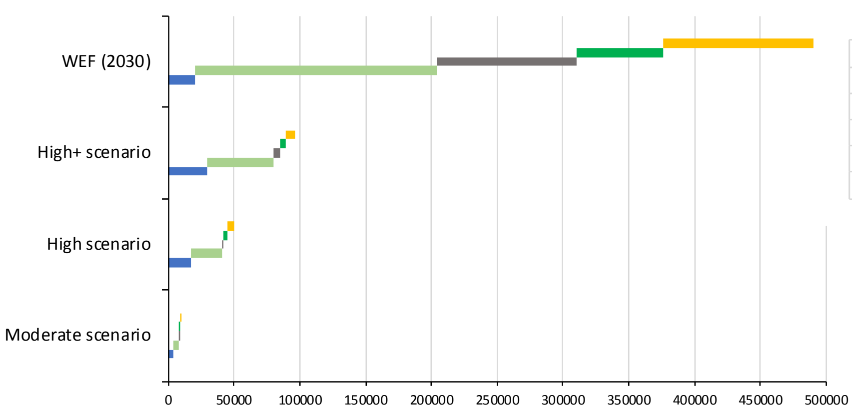
Required CAPEX investment



Comparison to hist. CAPEX



Feedstock needs compared to projected availability



	Moderate scenario	High scenario	High+ scenario	WEF (2030)
Waste and byproducts FOGs	3635	16982	29674	20417
Energy crops	4164	23585	50617	183750
Crop residues	443	1747	4555	106167
Forestry residues	718	3110	4852	65333
MSW	1247	4689	7183	114333
Forecasted SAF (2035)	10208	50113	96881	

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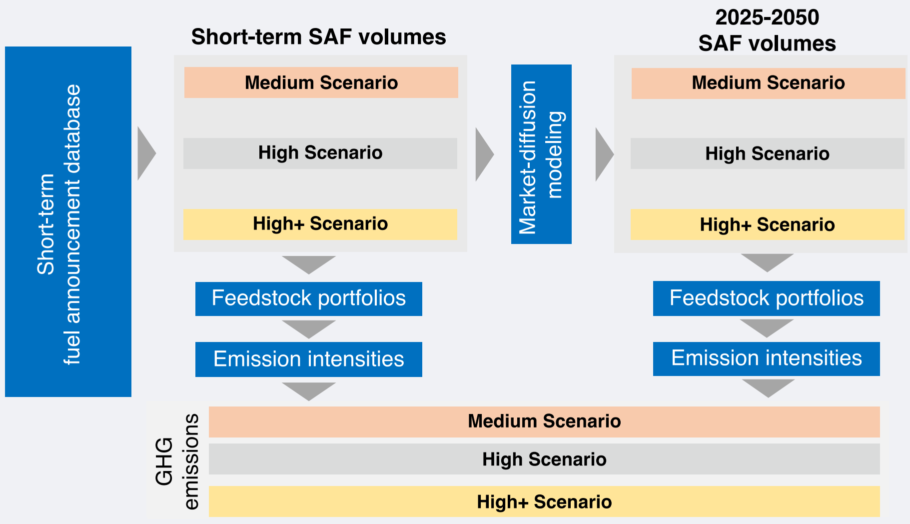

Major Accomplishments (to date) *(focus topic)* :

- SAF production scenarios and associated range of GHG emission reductions out to 2050 finalized.

Future Work / Schedule (MIT-ASCENT 1):

- Run LCA for additional pathways to be considered under CORSIA (e.g.: catalytic thermolysis)
- LCA and TEA and production potential of PtL Fuels, considering different carbon sources
- Analysis of optimized production scenarios for SAF in the U.S. under uncertainty

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