MJ0

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Sustainable Aircraft Propulsion Vehicle Technologies and Fuels

Sustainable Aviation Fuels

Joshua Heyne, Ph.D.
Director, Bioproducts, Sciences, and Engineering Laboratory
Co-director, WSU-PNNL Bioproducts Institute
Battelle Distinguished Professor
Scientist, PNNL (Joint Appointment)
Co-chair, CAAFI R&D Committee

Sustainable Aviation in WA:
Connecting Policy, Technology, Infrastructure and Workforce Development Needs

2023 WSAS SYMPOSIUM

17 August 2023
The Museum of Flight, Seattle

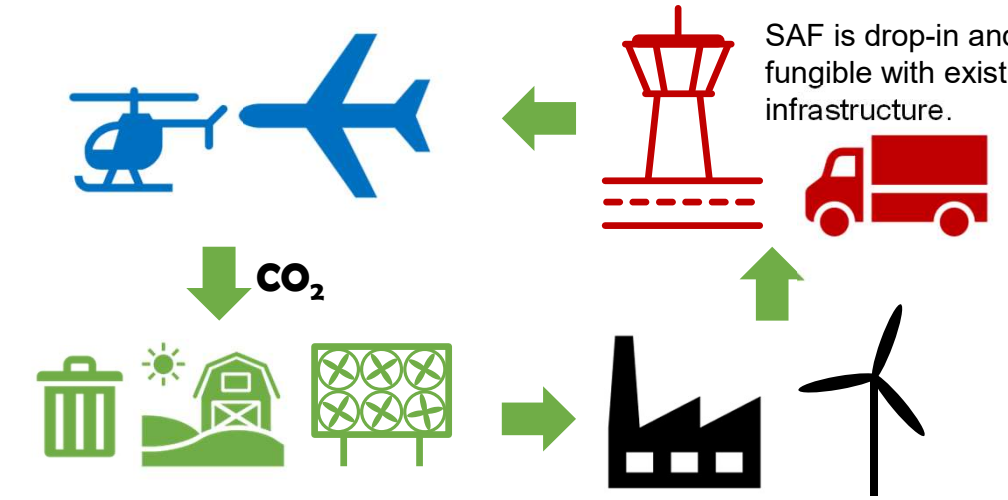
Slide 1

MJ0 Think about what is the one takeaway message in one sentence you want to leave BETO with for each slide
Male, Jonathan, 2023-07-10T22:12:51.386

Where does SAF come from?

SAF can be produced from many carbon sources:

- **Waste sources** such as used cooking oil, municipal solid waste, sewage sludge, woody and agriculture residues
- **Purpose-grown crops** such as oil seeds and corn ethanol
- **Power-to-liquids** such as point source or direct air capture CO_2



Heyne, A Decarbonized Aviation Path with Sustainable Aviation Fuel, ASME Global Gas Turbine News, Sept. 2023.

joshua.heyne@wsu.edu

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All SAFs to date are drop-in

Jet fuel must meet detailed specs for safety

Aircraft and engines are **certified** for fuel **specified in a standard**, such as Jet A/A-1 (ASTM D1655).

Fuel Specification (ASTM D1655)

Engine Operating Limitations
- fuel specification

Aircraft Operating Limitations
- engine limitations for aircraft limitations

Aircraft Operator (Airlines) Operating Rules
- must adhere to aircraft and engine limitations

Engine, aircraft, and infrastructure do not 'see' any difference between a SAF blend and a conventional fuel.

All approved SAF blends are currently "drop-in" or "equivalent" to Jet A/A-1

Drop-in = fleetwide infrastructure compatible

If a fuel were not "equivalent" to Jet A/A-1, the fuel would require its own fuel specification, the fuel would require separate handling, and the aircraft and the engine would require certification to that fuel

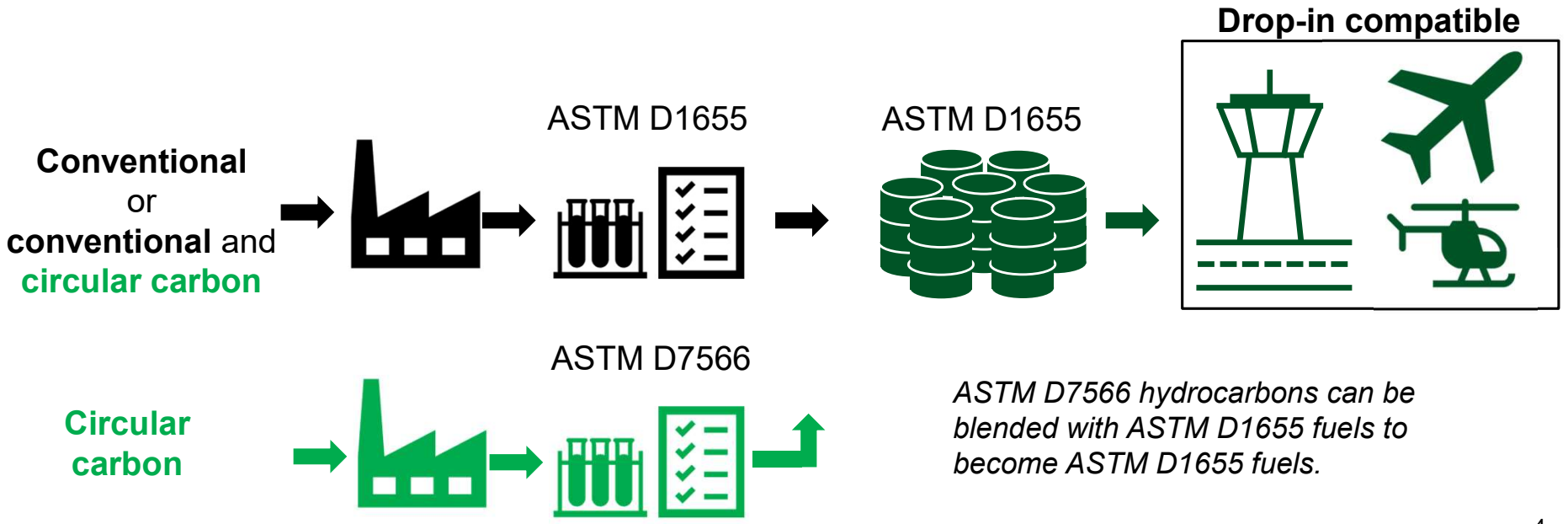
Kramer, S., Andac, G., Heyne, J., Ellsworth, J., Herzig, P., & Lewis, K. C. (2022). Perspectives on Fully Synthesized Sustainable Aviation Fuels: Direction and Opportunities. *Frontiers in Energy Research*, *9*. https://doi.org/10.3389/fenrg.2021.782823

joshua.heyne@wsu.edu

Currently, SAF blend components are blended into Jet A/A-1 to yield Jet A/A-1

Jet A/A-1 + SAF = Jet A/A-1

(ASTM D1655 + ASTM D7566 = ASTM D1655)



ASTM D7566 hydrocarbons can be blended with ASTM D1655 fuels to become ASTM D1655 fuels.

joshua.heyne@wsu.edu

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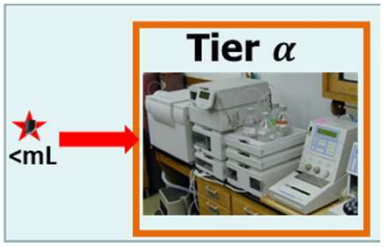
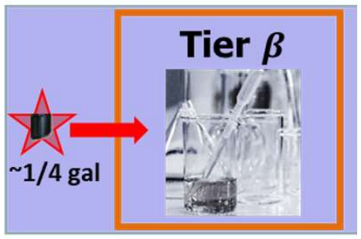
Safety first and safety last

SAFs are subjected to an extensive suite of testing

Prescreening





ASTM Qualification

Phase1: 6 Months
~ $50k (Testing Cost)
~ 200 liter Neat Fuel

6 Months to 1 Year
~ $350k (OEM Cost)

Tier 1

Specification Properties

Tier 2

Fit-For-Purpose Properties

Phase 1 ASTM Research Report

SAFRAN BOEING Honeywell Rolls-Royce AIRBUS

OEM Review & Tier 3 & 4 Requirements

Tier 3

Component/Rig Testing

Tier 4

Engine/APU Testing

Phase 2 ASTM Research Report

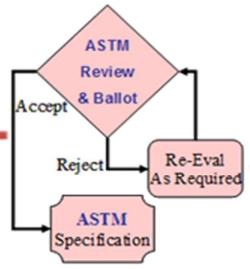
SAFRAN BOEING Honeywell Rolls-Royce AIRBUS

OEM Review & Approval

6 Months – 1 Year
~ $1M (OEM Cost)

Phase 2: 2 – 3 Years
~ $4M (Testing Cost)
~100k – 450k liter Neat Fuel

ASTM Specification
(ASTM D7566)



ASTM Balloting Process

FEDERAL AVIATION ADMINISTRATION

FAA Review

joshua.heyne@wsu.edu

Unblended SAF (neat, 100%)...is it  ?

100%

FT-SPK sbc → 

HEFA-SPK sbc → 

HFS-SIP sbc → 

FT-SKA sbc → 

ATJ-SPK sbc →   (depends on the producer)

CHJ sbc → 

HC-HEFA-SPK sbc → 

Kramer, S., Andac, G., Heyne, J., Ellsworth, J., Herzig, P., & Lewis, K. C. (2022).
Perspectives on Fully Synthesized Sustainable Aviation Fuels: Direction and Opportunities.
Frontiers in Energy Research, *9*. https://doi.org/10.3389/fenrg.2021.782823

 Identical to Jet A/A-1 (?) (fleetwide compatible, drop-in)

 Like Jet A/A-1 (limited fleet compatible, non-drop-in)

 Not-like Jet A/A-1 (not acceptable as a stand-alone jet fuel)

		
aromatics	~17%	~0%
energy cont.	~43.2MJ/kg	+ 0-3%
density	~800kg/m^3	- 0-8%
Cetane #	~45	
Sulfur	~500-800ppm	~0ppm

Variation of composition among pathways and even among producers for a pathway
When unblended they do not all result in one and the same product
A specification is needed to define 100% SAF (in progress; early stages)

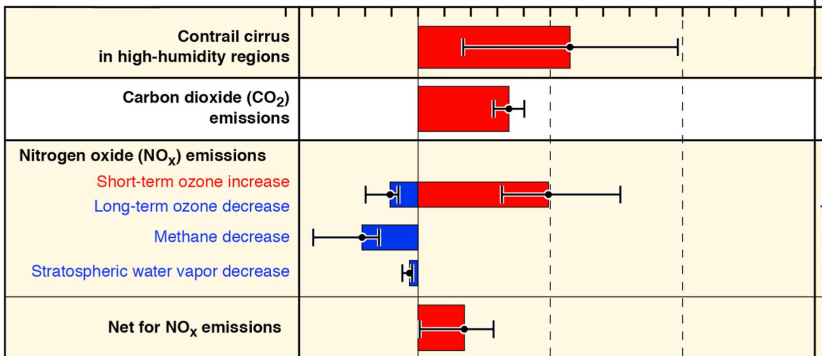
joshua.heyne@wsu.edu

100% SAF

beyond net-zero carbon

Contrails may contribute more to the radiative forcing of aviation than CO_2 emissions

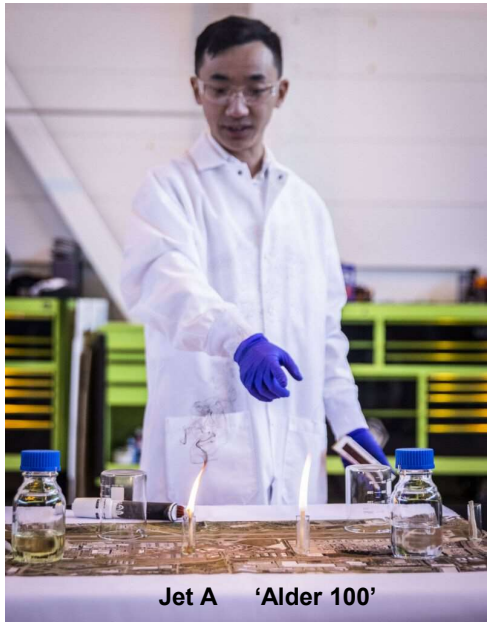
Global Aviation Effective Radiative Forcing (ERF) Terms (1940 to 2018)

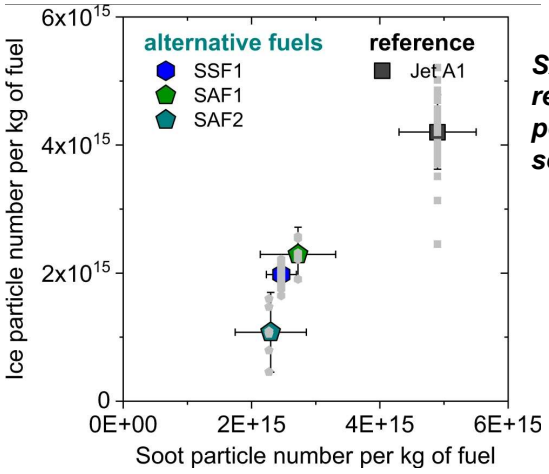


	ERF (mW m^{-2})	RF (mW m^{-2})	ERF / RF	Conf. levels
Contrail cirrus in high-humidity regions	57.4 (17, 98)	111.4 (33, 189)	0.42	Low
Carbon dioxide (CO_2) emissions	34.3 (28, 40)	34.3 (31, 38)	1.0	High
Nitrogen oxide (NO_x) emissions				
Short-term ozone increase	49.3 (32, 76)	36.0 (23, 56)	1.37	Med.
Long-term ozone decrease	-10.6 (-20, -7.4)	-9.0 (-17, -6.3)	1.18	Low
Methane decrease	-21.2 (-40, -15)	-17.9 (-34, -13)	1.18	Med.
Stratospheric water vapor decrease	-3.2 (-6.0, -2.2)	-2.7 (-5.0, -1.9)	1.18	Low
Net for NO_x emissions	17.5 (0.6, 29)	8.2 (-4.8, 16)	----	Low

Lee, D. S., et al., (2020). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, 117834. https://doi.org/https://doi.org/10.1016/j.atmosenv.2020.117834

WSU Ph.D. student (Harrison Yang) at the Paine Field press event illustrating the sooting propensity of Jet A (left) versus 'Alder 100' (right).

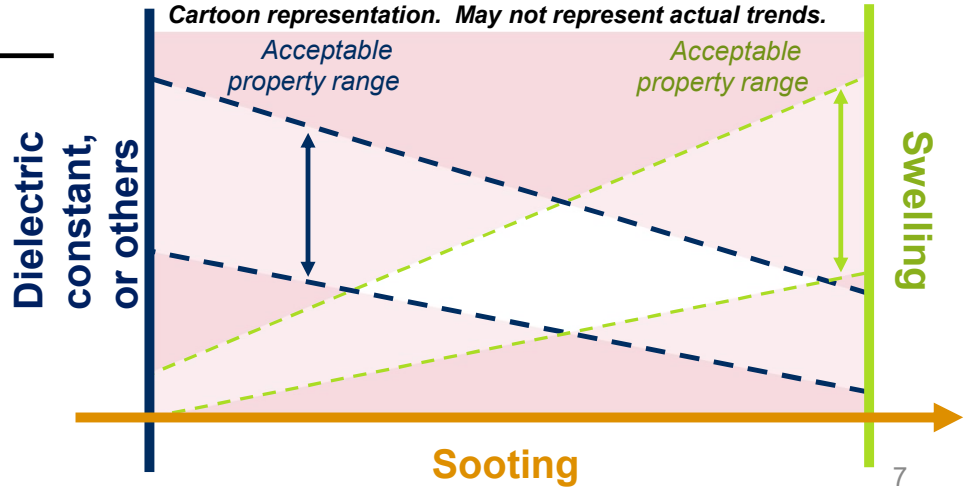




SAF composition could reduce contrails and persistent cloudiness via soot reduction

Voigt, C. et al., (2021). Cleaner burning aviation fuels can reduce contrail cloudiness. *Communications Earth & Environment 2021*. https://doi.org/10.1038/s43247-021-00174-y

Cartoon representation. May not represent actual trends.



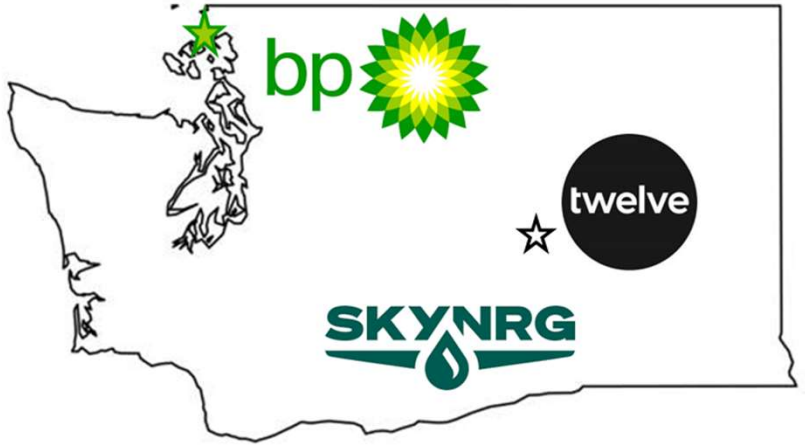
joshua.heyne@wsu.edu

Thank you.

joshua.heyne@wsu.edu

What is happening with SAF production in the US and WA?

- WA has **three production facilities** announced
  - BP in Cherry Point (HEFA)
  - SkyNRG Americas (Alcohol to Jet)
  - Twelve in Moses Lake (Power to Liquids)
- **1.95 billion gallons of SAF production capacity** is planned, pending FID, post-FID, in construction or operational in the US in 2030.
  ref: Boeing SAF Dashboard / BloombergNEF



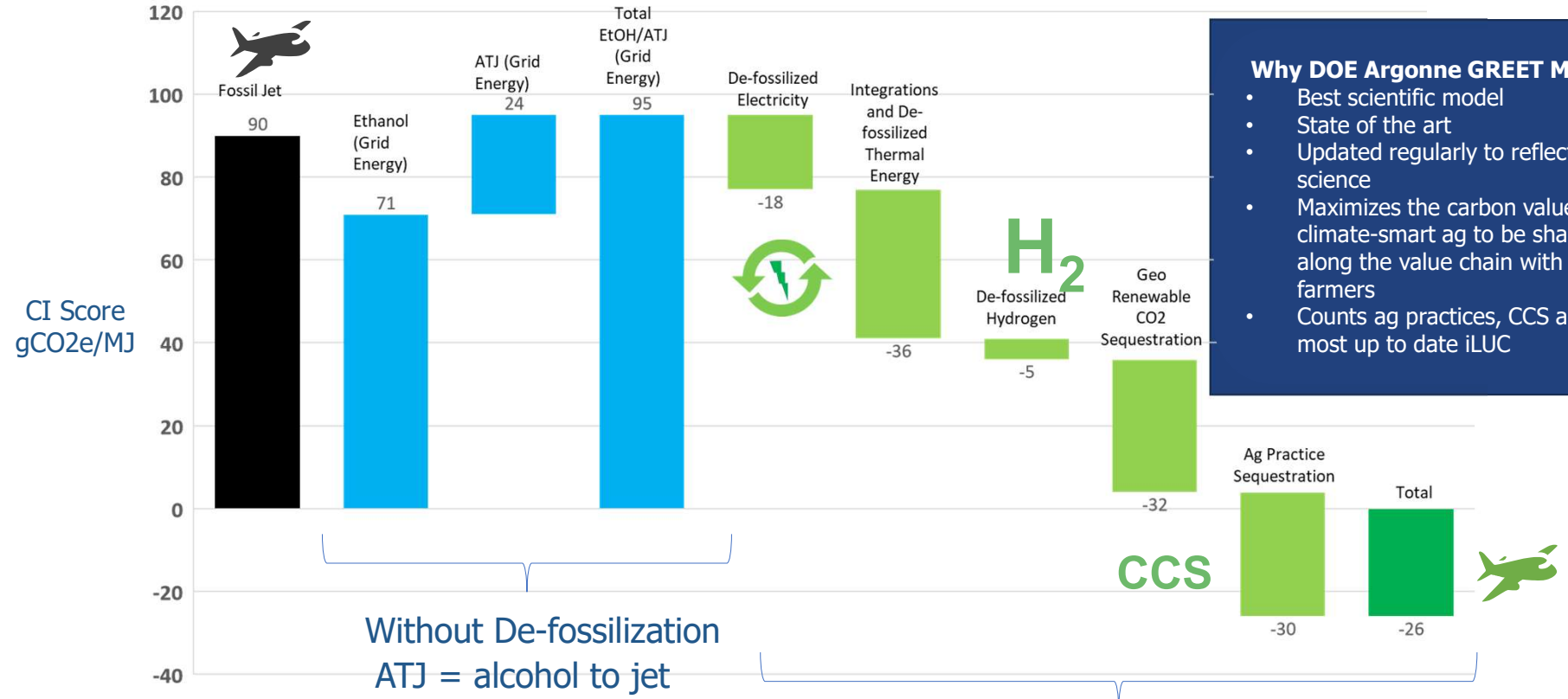
*"Washington has been thinking about sustainable aviation for more than a decade, and **we're on the cusp of enabling the best, most well-thought-out policy that provides the most support out of any state in the country**."*
— John Plaza, chief investment officer for SkyNRG Americas, which plans to build a $600 to $800 million SAF plant in Washington to open by 2029,
AWB, Sustainable aviation fuel ventures plan launch in Washington, June 2023

SAF Grand Challenge:
- 3 billion gallons of domestic SAF production by 2030
- 35 billion gallons of domestic SAF production by 2050

joshua.heyne@wsu.edu

An exemplar path to carbon negative SAF

PUTTING IT ALL TOGETHER WITH ARGONNE GREET: HOW WE ARE PLANNING TO DRIVE CI DOWN



Why DOE Argonne GREET Model?

- Best scientific model
- State of the art
- Updated regularly to reflect new science
- Maximizes the carbon value from climate-smart ag to be shared along the value chain with farmers
- Counts ag practices, CCS and has most up to date iLUC

ILUC – Indirect Land Use. CCS – Carbon Capture Sequestration. CI – Carbon Intensity

Courtesy of Eric Frey, Ph.D., VP of Finance, Gevo

100 % SAF
Drop-in vs. non-drop-in (Jet-X)

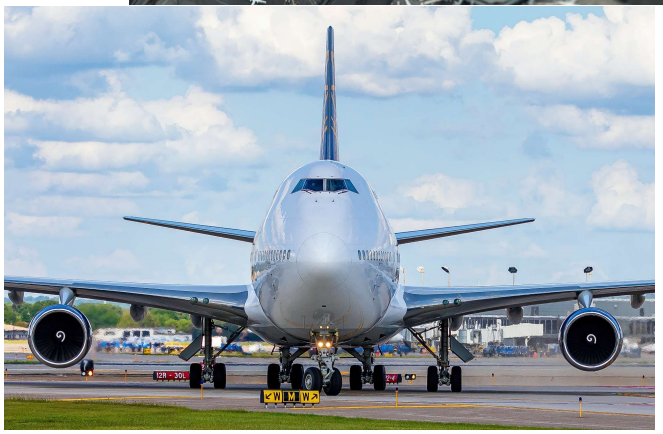
		
Description:	**Fully formulated** Jet A/A-1 composition	**Compositional subset** of Jet A/A-1 composition
Applicability:	Fleet Wide drop-in	Targeted or Limited for designated aircraft/engines only, not fleet-wide compatible
Example pathways:	CHJ (D7566 Annex A6), FT-SKA (D7566 Annex 4), future: ATJ-SKA, HEFA-SKA, blending of blend components	FT-SPK (D7566 Annex A1), HEFA-SPK (D7566 Annex A2), certain type ATJ-SPK (D7566 Annex A5)
Specification:	ASTM D7566	**New standard needed**
FAA Certification:	Not required	**Required for each intended aircraft, engine model**
Supply chain/ handling/ storage:	Separate supply chain, handling, storage not required	Separate supply chain, handling, storage required

Adopted from Andac, G., Kramer, S., Moving towards 100% SAF use, CAAFI, June 2021.

joshua.heyne@wsu.edu

What would change if we switched to SAF?

Fossil *vs.* *SAF*



For non-100% drop-in SAF routes

joshua.heyne@wsu.edu