
Wisconsin Energy Institute – Forward in Energy Series
Tuesday, 27Jan’26 - 4:30 PM Virtual

**Moderator**
**Steve Csonka, Executive Director, CAAFI**

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ALTERNATIVE FUELS INITIATIVE

**Significant progress, but miles to go**

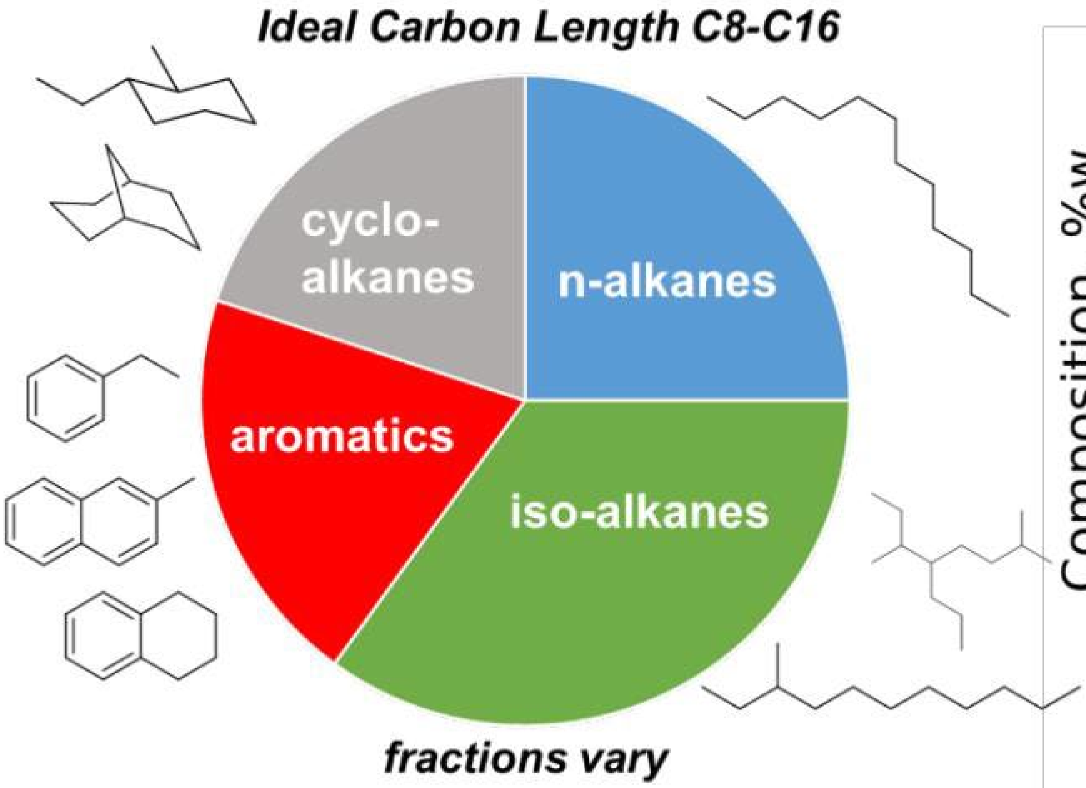

**First flight from continuous commercial production of SAF**

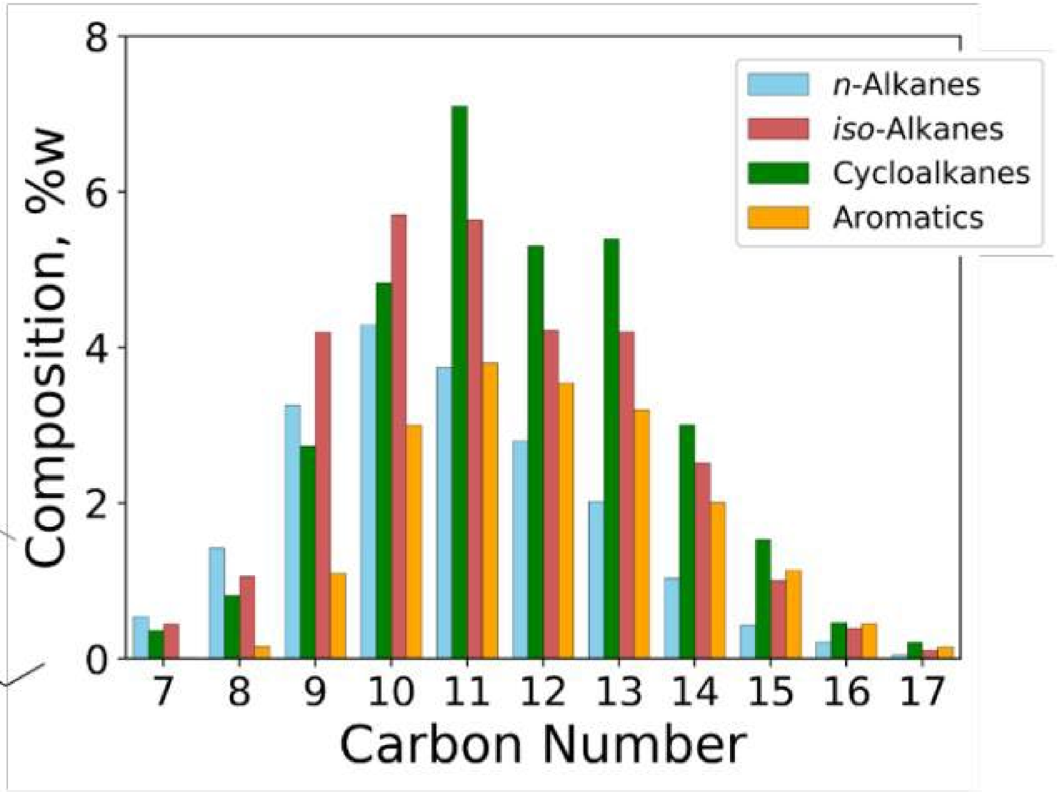
**UAL 0708, 10 March 2016, LAX-SFO**

**Fuel from World Energy - Paramount (HEFA-SPK 30/70 Blend)**
**Facility idled since Apr’25D**

# Typical jet fuel chemical composition

## Mixture of pure hydrocarbons




**Aromatics are limited to 25%**

**Olefins and heteroatoms are limited (not allowed)**

- Olefins (<1%) (gum formation)
- S, N, O containing (limited allowance)

Pie chart adapted from Tim Edwards
Composition/Carbon number from Josh Heyne

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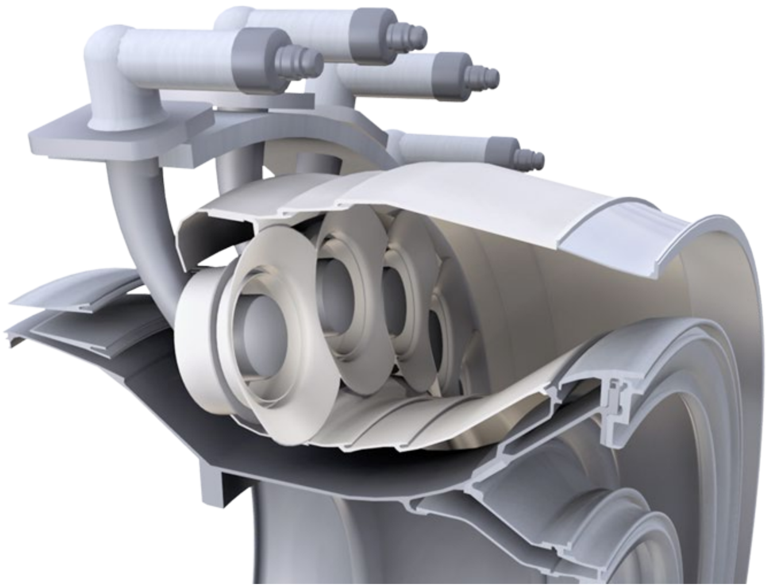
# Jet (turbine) fuel functional requirements

## Foundation for aircraft's certification basis

### How does the aircraft use fuel . . .

- As a coolant (heat transfer media)
- As a lubricant
- As a hydraulic fluid
- As a ballast fluid, swelling agent, capacitance agent, …
- And finally, as an energy source



**ASTM D-1655**

- Acidity
- Aromatics, max%
- Sulfur
- Distillation
- Flash Point
- Density
- Freeze pt
- Viscosity
- Heat of Combustion
- Copper strip corrosion
- JFTOT
- Existent gum
- MSEP
- Electrical conductivity

### Need: Efficiency and safety paramount

- High energy content: volumetric & mass
- Stable: high flash point (no explosions), low freeze point (liquid at -40C)
- Unique properties enable required Operability

### Turbine fuel used for multiple purposes (including for non-turbine use)

**…So its formulation/production has to be carefully controlled to get the right fit-for-use properties, and maintain certification basis for existing fleet**

# SAF (Sustainable Aviation Fuel)
## a.k.a. aviation biofuel, biojet, synthetic aviation turbine fuel (SATF)

**Aviation Fuel:** Maintains the certification basis of today's aircraft and jet (gas turbine) engines by delivering the properties of ASTM D1655 – Aviation Turbine Fuel – **enables drop-in approach – no changes to infrastructure or equipment, obviating incremental billions of dollars of investment**

**Sustainable:** Doing so while taking Social, Economic, and Environmental progress into account, **especially addressing GHG reduction through YE 2024**

**How:** Creating synthetic jet fuel with biochemical and thermochemical processes by starting with a different set of carbon molecules than petroleum … **a synthetic comprised of molecules essentially identical to petroleum-based jet** (in whole or in part)

Delivered to the wing of the aircraft as a blended (today) drop-in fuel using existing infrastructure: pipeline, ship/barge, rail, truck

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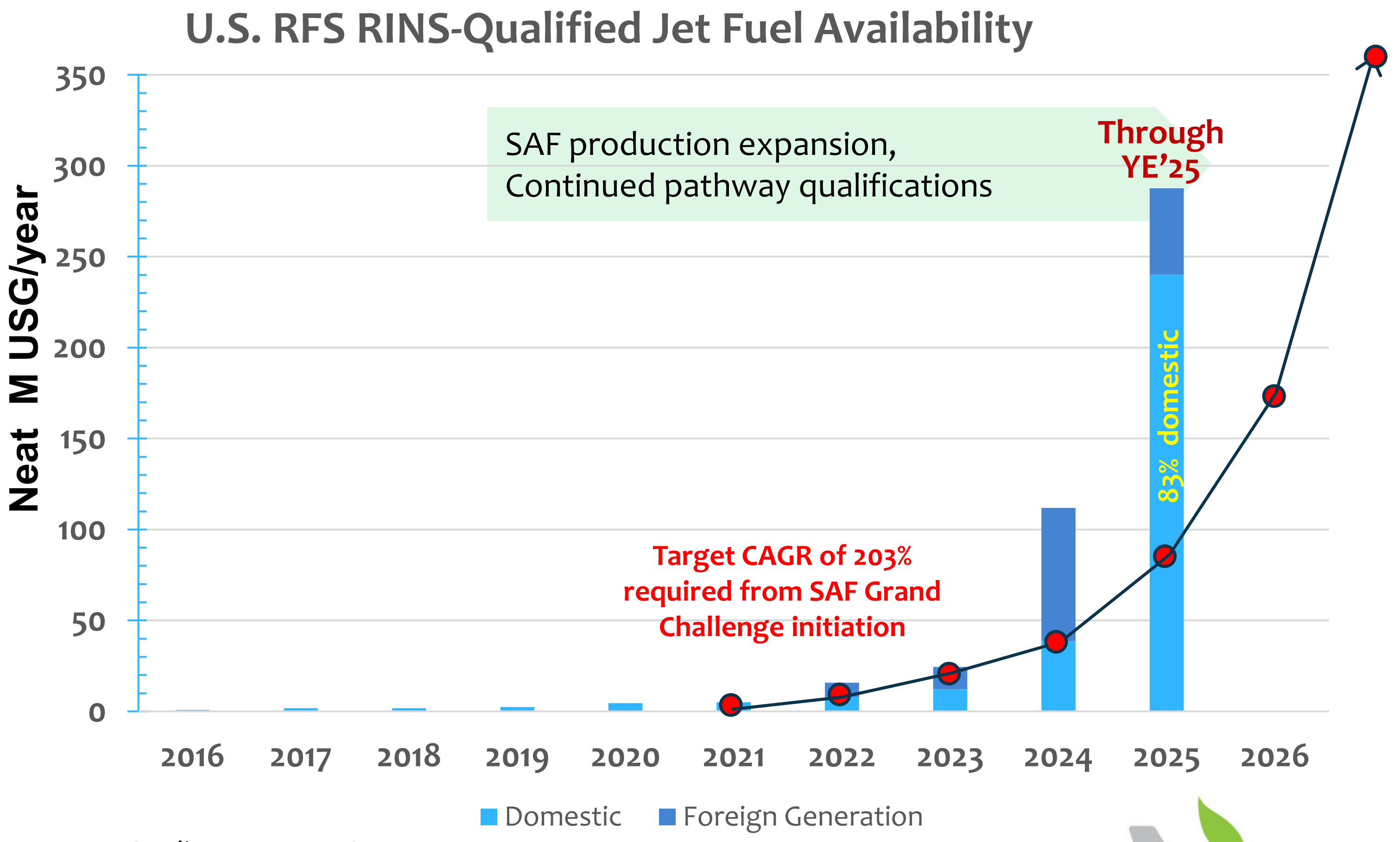
# Where we stand on U.S. neat SAF availability

## Expansion underway, still early

* Approaching 10 years of sustained commercial production and use
* Commercial, BizAv, Corporates engaged; U.S.G. fostering R&D
* Facilities in com’l operation & upgrading, others in physical construction or commissioning
* Cost delta still a challenge, with practicalities favoring renewable diesel, policies transient
* Worldwide: IATA expected 2 M tonnes production in 2025 (660 M usg, representing 0.7% of airline usage)




Credit: FAA, EPA, CAAFI
2016-2025: Reflects EPA Reported RINS Data (as of 10Jan’26 summary)

# U.S. SAF production capability forecast

## Announced intentions, neat*

Est. Year-end Production (M gpy)

**By YE '25** (~508 M; prior ~39 M)
- LanzaJet — Freedom Pines 10
- Phillips 66 — Rodeo 150
- Diamond Green Diesel — Port Arthur 235
- Par Hawaii — Honolulu 36
- New Rise Renewables Reno — Reno 38

**2026** (~628 M)
- Montana Renewables — Great Falls' +120

**2027** (~1.47B)
- New Rise Renewables Reno — Reno 2 40
- World Energy — Paramount B +230
- Montana Renewables — Great Falls'' +150
- Summit Agricultural Group (A Principled Approach.) — Houston 250
- USA BioEnergy (Renewable Energy Solutions) — Bon Wier, TX 53
- LanzaJet — Hennepin 120

**2028** (~2.02 B)
- New Rise Renewables Reno — FL & NC 80
- Aemetis — Carbon Zero #1 Riverbank 45
- World Energy — Houston 250
- DG Fuels — St. James, LA 120

**2029** (~2.23 B)
- gevo — ATJ-60 SD 60 … Or ND 30
- Aemetis — Carbon Zero Riverbank+ 44
- Green Plains / Tallgrass — Blue Blade Energy Tbd, Midwest 135
- SkyNRG Americas — NW #1 30

**2030** (~2.35 B)
- DG Fuels — Nebraska 120

SAFGC 3.0 B

Exact Timing & Production tbd

**Unannounced or In-development efforts:**
- ~200 additional new-entrants collaborating with CAAFI & CH's
- Outlined expansion goals of existing/pending producers
- Refinery co-processing / conversion
- Renewable Diesel switching resulting from policy shifts

- Not comprehensive; CAAFI estimates (based on technology used & public reports) where production slates are not specified. Does not include various small batches produced for testing technology and markets. New companies engaging at about 2-3 per month
- Does not include fractions of substantial Renewable Diesel capacity (existing and in-development) that can be shunted to SAF based on policy support
- Similar dataset from Argus suggests about 3.4 B gpy from 29 U.S. facilities by YE 2030

27 January 2026

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# Additional Enablers

* Continued technical breakthroughs & addition of pathways
* Engagement of oil majors on issues like co-processing and refinery of the future
* Proliferation of enabling organizations/frameworks: industry, academia, PPPs
  * Sustainability protocols, SAF registries, Book & Claim systems, Regional Initiatives, …
* Policy Support: RDD&D, subsidies, capital
  * Continued interest to wean-off petroleum in many countries
  * Support driven by recognition of value to economy where feedstocks are prevalent
* Additional work needed on "appropriate conversion processes for targeted feedstocks"
* Continued removal of technical barriers (blending requirements, distribution)

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# Additional Enablers Discussion

* Continued technical breakthroughs & addition of pathways
* Engagement of oil majors on issues like co-processing and refinery of the future

**Elvis Ebikade**, Director of Aviation, BIOLEUM



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# SAF Progress - technical

* SAF are becoming increasingly technically viable
  * Aviation now knows we can utilize numerous production pathways: biochemical, thermochemical, combined bio-thermos:

    8 D7566 pathways, 12 in process – more in 'pipeline'

    3 D1655 pathways (co-processing), 4 in-process
* Challenge remaining is achieving reasonable cost and expanding production
  * Exploring expanded use of all major sustainable feedstocks
    * Fats, oils, and greases; sugars & starches; recalcitrant lignocellulose
    * Newer crops associated with improved farming practices (covers, rotations, intercropping)
  * Additional focus on 24x7, aggregated, low-cost types to enable affordability and capitalization
    * Circular economy byproducts
    * 'Waste streams' – anything with a disposal cost
      * Food processing
      * Industrial processes



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| ASTM D7566 Annex | Technology Type | Process Feedstock | Process Feedstock Sources | Blend Requirement | Certification Date | Technology Developer*/ Licensor | Commercialization Entities |
|---|---|---|---|---|---|---|---|
| A1 | Fischer-Tropsch Synthetic Paraffinic Kerosene (**FT-SPK**) | Syngas (CO and $H_2$ at approximately a 1:2 ratio) | Gasified sources of carbon and hydrogen: Biomass such as municipal solid waste (MSW), agricultural and forestry residues, wood and energy crops; Industrial off-gases; Non-renewable feedstocks such as coal and natural gas. | Yes, 50% max | 2009 | ****Sasol**, Shell, Velocys, Johson Mathey/BP, … | Sasol, Shell, Fulcrum, Red Rock, Velocys, Loring, Clean Planet Energy, … |
| A2 | Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (**HEFA-SPK**) | Fatty Acids and Fatty Acid Esters | Various lipids that come from plant and animal fats, oils, and greases (FOGs): chicken fat, white grease, tallow, yellow grease, brown grease, purpose grown plant oils, algal oils, microbial oils. | Yes, 50% max | 2011 | **UOP/ENI,** Axens IFP, Neste, Haldor-Topsoe, UPM, Shell, REG … | World Energy, Neste, Total, SkyNRG, SGPreston, Preem, …, many entities using technology for renewable diesel too |
| A3 | Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (**HFS-SIP**) | Sugars | Sugars from direct (cane, sweet sorghum, sugar beets, tubers, field corn) and indirect sources (C5 and C6 sugars hydrolyzed from cellulose); | Yes, 10% max | 2014 | **Amyris** | Amyris / Total |
| A4 | Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics (**FT-SPK/A**) | Syngas | Same as A1, with the addition of some aromatics derived from non-petroleum sources | Yes, 50% max | 2015 | **Sasol** | none yet announced |
| A5 | Alcohol to Jet Synthetic Paraffinic Kerosene (**ATJ-SPK**) | C2-C5 alcohols (limited to ethanol, iso-butanol, and isobutene at present) | C2-C5 alcohols derived from direct and indirect sources of sugar (see A3), or those produced from microbial conversion of syngas | Yes, 50% max | 2016 | **Gevo, Lanzatech,** (others pending including Swedish Biofuels, Byogy, ...) | Gevo, Lanzatech |
| A6 | Catalytic Hydrothermolysis Synthesized Kerosene (**CH-SK, or CHJ**) | Fats, Oils, Greases | Same as A2 | Yes, 50% max | 2020 | **Applied Research Associates** (ARA) / CLG | ARA, Wellington, UrbanX, Euglena, ... |
| A7 | Hydroprocessed Hydrocarbons, Esters and Fatty Acids Synthetic Paraffinic Kerosene (**HHC-SPK**, or **HC-HEFA**) | Algal Oils | Specifically, bio-derived hydrocarbons, fatty acid esters, and free fatty acids. Recognized sources at present only include the tri-terpenes produced by the Botryococcus braunii species of algae. | Yes, 10% max (fast track) | 2020 | **IHI Corporation** | IHI |
| A8 | Alcohol to Jet Synthetic Kerosene with Aromatics **(ATJ-SKA)** | Any single, or combo of 2 or more, C2-C5 alcohols | Multiple | Yes, 50% max | 2023 | **Swedish Biofuels** | Swedish Biofuels; Others TBD |

# ASTM Qualifications Landscape

## Jan 28, 2026

### Early data & discussions

**AtJ-SAK**
(Vertimass)
**AtJ**
(UFT)
**HBtJ**
(Visolis)
**TtJ**
(Captis Aire)
…

### Tier 1 & 2

**PtJ-SKA**
(OMV)
**TOtJ**
(UPM)
**SBtJ**
(Firefly)
**LP-HEFA-SKC**
(REVO)
**KtJ-SPK**
(BioVeritas)

### OEM review

**MtJ-CKA**
(Topsoe)
**ItJ-SCP**
(CleanJoule)

### Tier 3 & 4

**HDO-SAK**
(Marathon)

### OEM & regulatory agency review

**MtJ-SPK**
(ExxonMobil, Honeywell)
**HEFA-SKA**
(CSIR-IIP)

### ASTM balloting

### Qualification

**ASTM D7566**
**A1: FT-SPK**
**A2: HEFA-SPK**
**A3: SIP**
**A4: FT-SKA**
**A5: AtJ-SPK**
**A6: CHJ**
**A7: HHC-HEFA**
**A8: AtJ-SKA**

**Acronyms:**

| | |
|---|---|
| **AtJ-SKA:** | Alcohol-to-Jet Synthetic Kerosene with Aromatics |
| **AtJ-SPK:** | Alcohol-to-Jet Synthetic Paraffinic Kerosene |
| **CHJ:** | Catalytic Hydrothermolysis Jet |
| **CPK-0:** | Cycloparaffinic Kerosene |
| **FT-SKA:** | Fischer-Tropsch Synthetic Kerosene with Aromatics |
| **FT-SPK:** | Fischer-Tropsch Synthetic Paraffinic Kerosene |
| **HBtJ:** | Hybrid Bio-Thermocatalytic Jet |
| **HDO-SAK:** | Hydro-deoxygenation Synthetic Aromatic Kerosene |
| **HEFA-SKA:** | Hydro-processed Esters and Fatty Acids Synthetic Kerosene with Aromatics |
| **HEFA-SPK:** | Hydro-processed Esters and Fatty Acids Synthetic Paraffinic Kerosene |
| **HHC-HEFA:** | Hydroprocessed Hydrocarbons, Esters and Fatty Acids |
| **ItJ-SCP:** | Isoprene-to-Jet Synthesized Cycloparaffins |
| **KtJ-SPK:** | Ketones-to-Jet Synthetic Paraffinic Kerosene |
| **LP-HEFA-SKC:** | Low Pressure HEFA Synthetic Paraffinic Kerosene Containing Cycloparaffins |
| **MtJ-CKA:** | Methanol-to-Jet Cycloparaffinic Kerosene with Aromatics |
| **MtJ-SPK:** | Methanol-to-Jet Synthetic Paraffinic Kerosene |
| **PtJ-SKA:** | Plastics-to-Jet Synthetic Kerosene with Aromatics |
| **SATF:** | Synthetic Aviation Turbine Fuel |
| **SBC:** | Synthetic Blending Component |
| **SBtJ:** | Sewage Biosolids to Jet |
| **SIP:** | Synthetic Iso-paraffins |
| **TOtJ** | Tall Oil to Jet |
| **TtJ:** | Terpenes-to-Jet |

### Fully-SATF Task Forces

**Drop-in Fully-SATF: Qual of pathways good for drop-in; also allow blends of SBCs**

**non-Drop-in Fully-SATF: Standardization only; for testing/certification**

### ASTM D1655 co-processing of alternate crude with petro-crude

**Lipids**

**Fischer-Tropsch**

**Hydroprocessed biomass**

**ASTM Task Force for "generic" co-processing**

**ASTM Task Force for pyrolysis oil from used tires**

**ASTM Task Force for waste plastics**

Gurhan Andac, GE Aerospace, ASTM D02.J06 Chair

# Additional Enablers Discussion

* Proliferation of enabling organizations/frameworks: industry, academia, PPPs
* Policy Support: RDD&D, subsidies, capital

**Jane McCurry**, Executive Director, Clean Fuels Michigan



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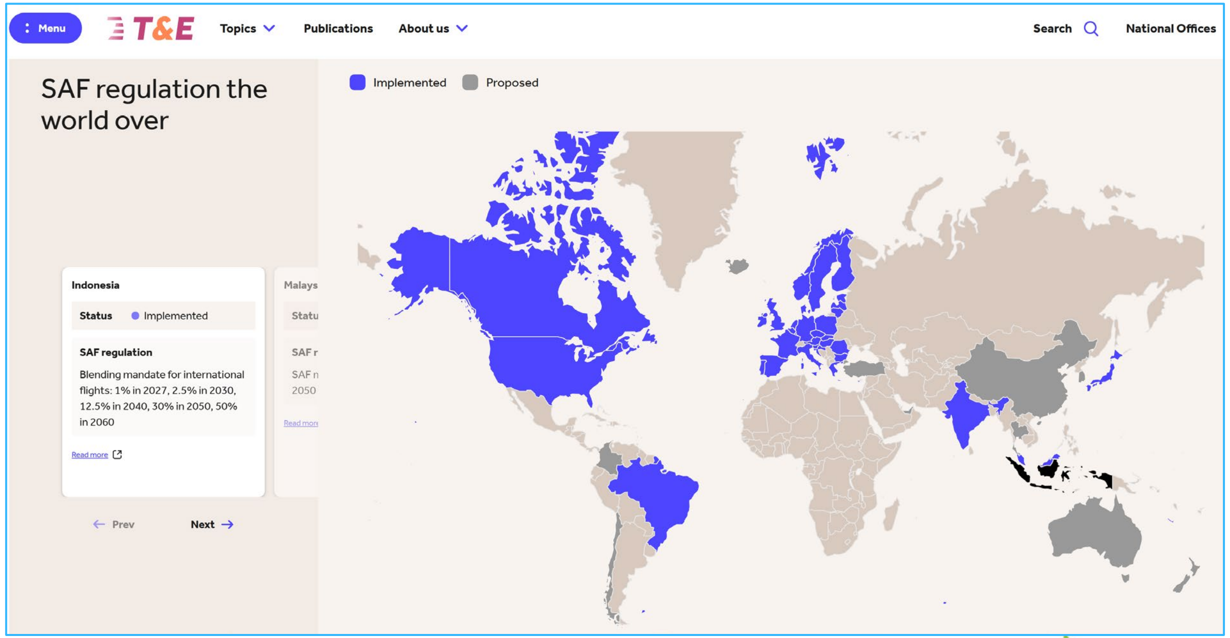
# Drivers: Strong & Expanding

- Avoidance of adverse industry-emission-spotlighting due expected continuous aviation growth trend
  - IATA goals – NZE by 2050 (majority of reduction, and likely to increase, is reliant of SAF)
  - Airlines own individual commitments (e.g. NZE op's by 2040-2070)
- Policy
  - CORSIA: 129 State voluntary participation at present; compulsory from 2027;
    - LTAG & stringency development likely to continue
  - Mandates on SAF usage multiplying in line with CORSIA ambitions (-5% by 2030)
    - Implemented in: Indonesia, Malaysia, Cyprus, India, EU, Brazil, Norway, Canada, Japan
    - Developing/Proposed in: Chile, China, S. Korea, UAE, Turkey, Lichtenstein, Thailand, Columbia, Australia, Iceland, Singapore, New Zealand
- Aviation-reliant businesses addressing predominance of jet fuel in their carbon footprints, demanding solutions

https://www.transportenvironment.org/topics/planes/saf-observatory/saf-around-the-world

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# Taking advantage of the SAF opportunities
## Via state & regional efforts & policies

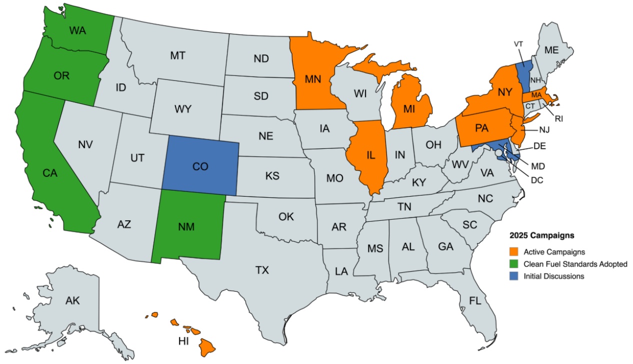

Policy & Resources

Achievements

Current Campaigns

Comment Letters & Reports

Videos





## Current Low Carbon Fuel Coalition Campaigns

The LCFC tracks state and federal policies to apprise LCFC members of all significant low carbon fuel standards policy developments by communicating and coordinating with state and federal policymakers, industry leaders, and NGOs to promote and expand the adoption of technology neutral, market-based low carbon fuel standards.

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- Communicating and coordinating with state and federal policymakers, industry leaders, and NGOs to promote the adoption of technology neutral, market-based low carbon fuel standards

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# Additional Enablers Discussion

- **Additional work needed on "appropriate conversion processes /feedstocks"**
- **Continued removal of technical barriers (blending requirements, distribution)**

**Tim Donohue,** WEI & GLBRC Director, Ira L. Baldwin Professor of Bacteriology, UW Foundation Fetzer-Bascom Professor



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# SAF technical progress at earlier TRL

* **Challenge remaining is achieving reasonable cost and expanding production**
  * Exploring expanded use of all major sustainable feedstocks
    * Lignocellulose abundant, but recalcitrant
  * Laser focus on Costs,  i.e. enabling competitive pricing
    * 24x7, aggregated, low-cost types to enable affordability and capitalization
    * Total product suite – fuels, chemicals, co-products (food, feed, fiber, … )
    * Co-products that enable business case
    * Co-processing with other industrial processes and needs.



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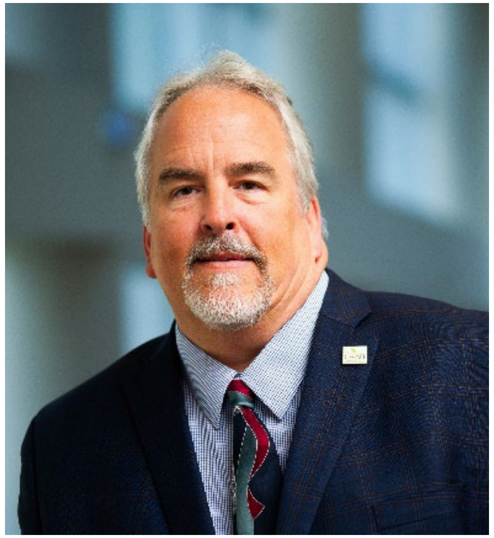

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