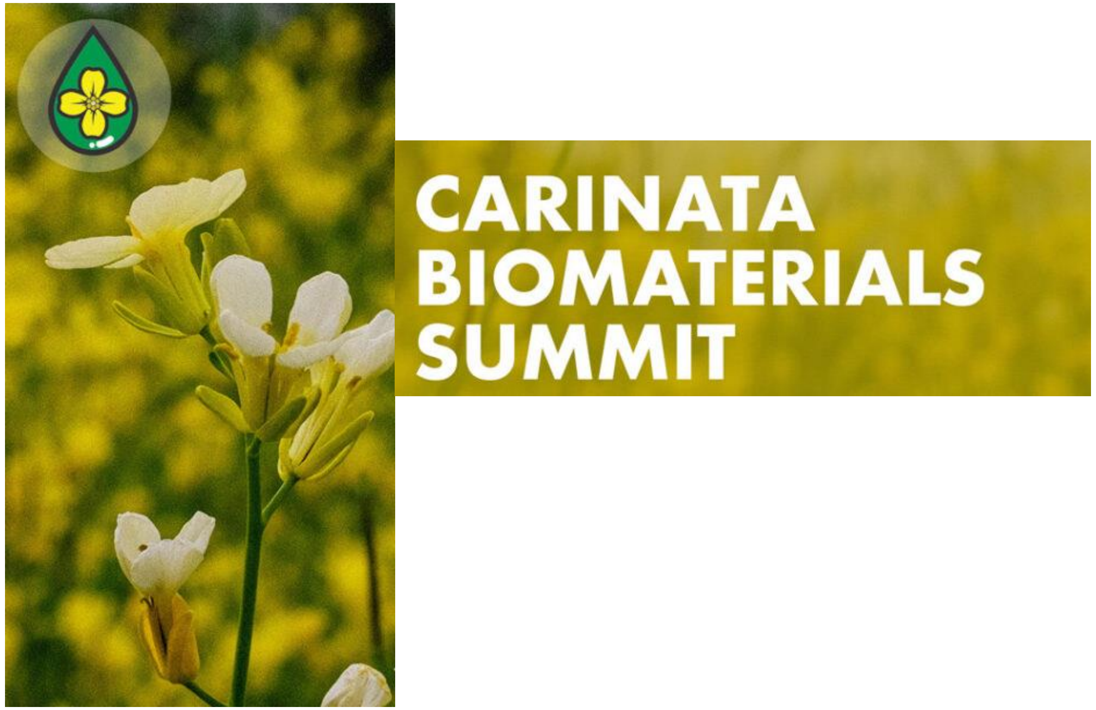
Sustainable Aviation Fuel (SAF) & Prospects for Carinata

Aviation Industry Interest in Lipid Feedstocks for SAF Production:



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20Jul'21

Overall industry summary on SAF:

SAF are key for meeting industry's commitments on carbon reductions

- Aviation enterprise aligned, representing a 26B gpy US & 97B gpy worldwide opt'y
- Jet fuel demand expected to increase for foreseeable future … 3 - 5% per year
- SAF delivers net GHG reductions of 65-100+%, other enviro services
- Segment knows how to make it; Activities from FRL 1 to 9, with many in "pipeline"
- CAAFI and others are working to foster, catalyze, enable, facilitate, …
- First 6 facilities on-line (5 from lipids), producing SAF at increasing run-rates,
- Commercial agreements being pursued, fostered by policy and other unique approaches
- Pathways identified for fully synthetic SAF (50% max blend today), enabling deeper net-carbon reductions

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A4A airlines' individual carbon / SAF commitments

Beyond NZC by 2050, and building to 2B gpy SAF by 2030 (commitments of Mar'21)

Alaska Airlines	NZC by 2040; Deal with Microsoft for SAF from SkyNRG/World Energy; SAF supply at SFO from Neste; SAF R&D investments with WSU-PNNL; Work with Carbon Direct
American Airlines	Allocation with Kuehne+Nagel and Deloitte ; 9 M usg SAF supply at SFO from Neste; Science based target by 2035 with SBTi; 10 M offtake from Prometheus
Atlas Air Worldwide	SAF demo work with Exolum/Avikor on Spain – Mexico flight;
Delta	Commits to be first global carbon-neutral airline; Collaboration with corporate customers (Deloitte, Takeda); 10% SAF by 2030
FedEx Express	Achieve NZC by 2040; $2B investment target; $100M on Yale Center for Natural Carbon Capture
Hawaiian Airlines	
jetBlue	NZC by 2040; 10% SAF penetration by 2030; Offtakes with SGPreston and World Energy
Southwest	Collaboration with NREL on new pathways; MOUs with Marathon a P66 – focus on CA refinery retrofits
United	UA First U.S. Airline to Pledge to Reduce Own Emissions by 50% (vs. 2005) by 2050; 13Sep'18. $40M SAF Investment Fund; 27Oct'19
UPS	30% SAF usage by global air fleet by 2035
Air Canada	Midterm goal, -20% from 2019 air ops by 2030. $40M investments in SAF and carbon reductions and removals. [14Mar'21, Leaveless (aircanada.com)]

Paradigm changing announcements

Intent to help close price premiums via traveler/shipper involvement

Rocky Mountain Institute + World Economic Forum

The Good Traveler — Leaves No Trace

Resilient and Sustainable Aviation Fuel (RSAF) credit

Clean Skies for Tomorrow Program
Use of Scope 3 (SAFc) credits, SABA program

SkyNRG Nordic

Fly Green Fund → Board Now — coalition for sustainable flying

Microsoft — Air France KLM — Delta

Purchase of SAF for US-Netherlands flights
(beyond offsetting employee travel)

United

Eco-Skies Alliance Program – 11 Customers
launch, 13Apr'21

Overall status of SAF:

* Making progress, but still significant challenges – only modest production: focus on enabling commercial viability <u>for which lipids will play an early / significant role</u>
* Potential for acceleration a function of engagement, first facilities' success replication, additional technologies and feedstocks that continue to lower production cost or improve Carbon Index
* Enabling/forcing policy continues to advance:
  * Renewable & Low Carbon fuel standards
  * Tax Treatment
  * International policy (ICAO CORSIA)
  * Usage mandates

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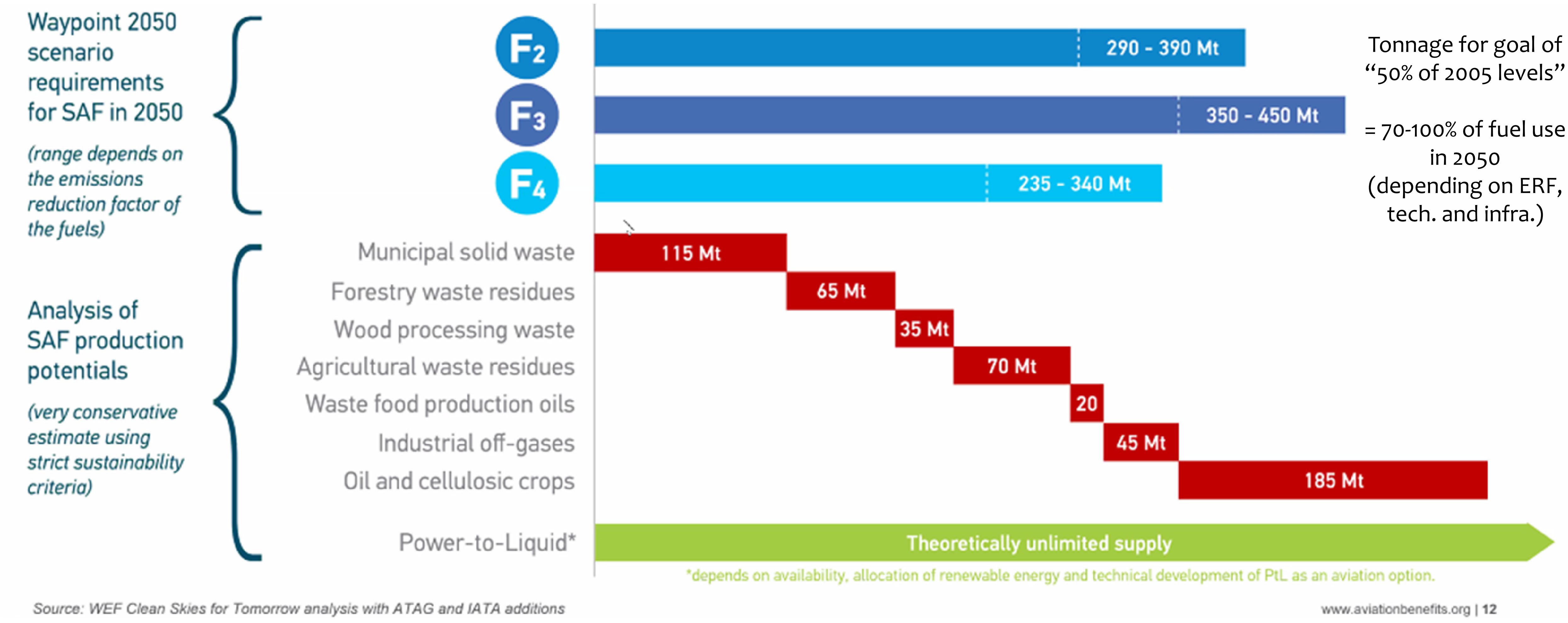
SAF production potential

Targets of opportunity that do not compete for food or land use change



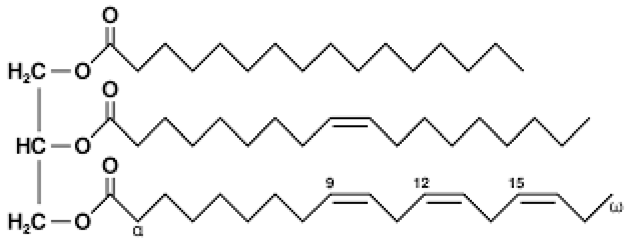
Tonnage for goal of "50% of 2005 levels"

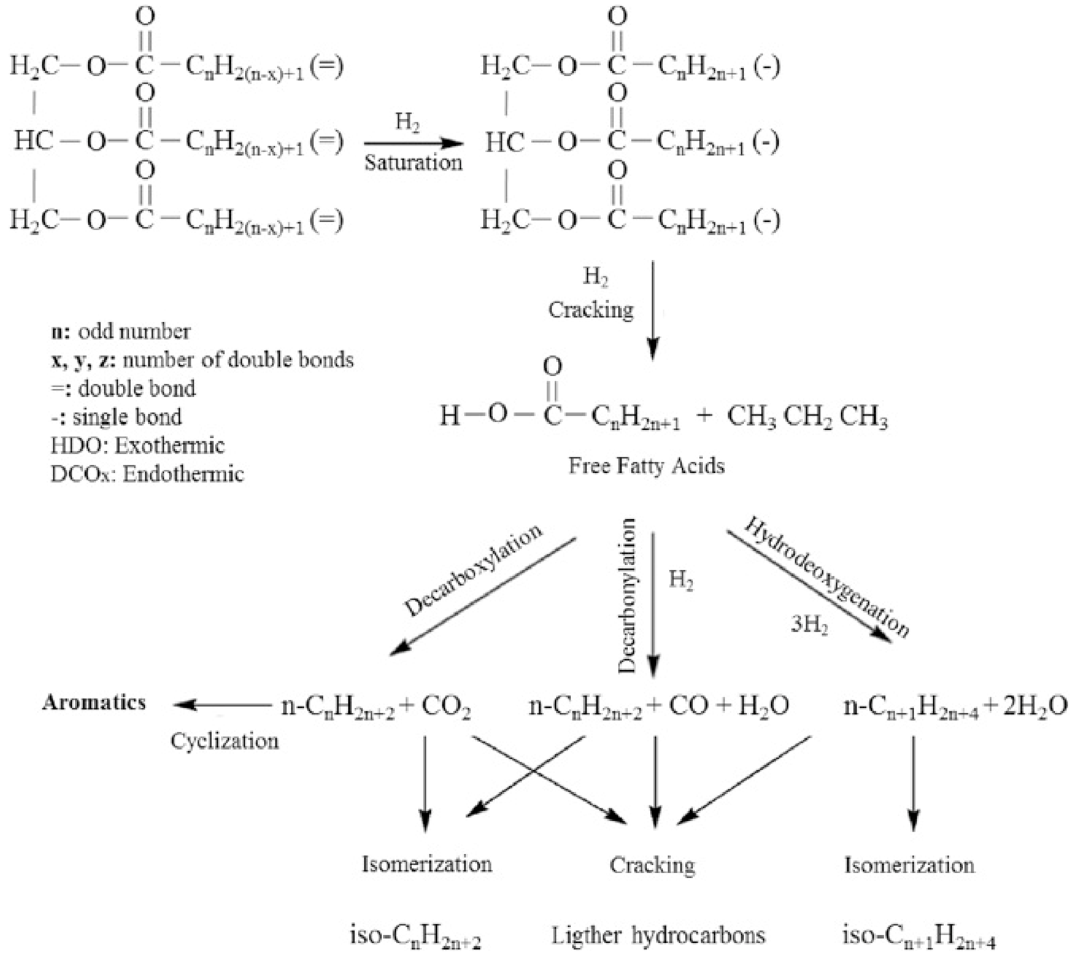
= 70-100% of fuel use in 2050 (depending on ERF, tech. and infra.)

Current focus on lipid solutions

Positive attributes

* **Straightforward – nature gives us a long chain TAG, with hydrocarbon suitable for use in jet & diesel**





Current focus on lipid solutions
Positive attributes

* Straightforward – nature gives us a long chain TAG, with hydrocarbon suitable for use in jet & diesel
* Lower CapEx and conversion cost to distillate fuels (SAF, HDRD)
* Significant domain knowledge and infrastructure around grains and oils
    * Handling, storage, processing, transport
    * Rapid energy densification via crush
    * Subsequent fungibility, and ease of working with fluid feedstock
* Main byproduct of protein/meal production – addresses other key concern – feeding a world of 10B
    * Other co-product markets in chemicals and materials
* Less farmer apprehension & up-front sunk costs with annuals versus perennial lignocellulosics
* Promise of winter cover oilseeds with minimal LUC/ILUC
* Potential for use of brown greases – relatively untapped market
* Eventual promise of ubiquitous algae production? Microbial lipids?
* Advanced work on oil production from non-traditional plants, or sequestration in lignocellulose

Current focus on lipid solutions

“Negative aspects” – being addressed e.g. in SPARC and IPREFER

* Poor opportunity for demand response from waste FOG
  * But, estimated by some at from 5-25% of US potential
* “Only so much viable acreage / viable fresh water” and “Food versus Fuel”
  * Some options will be viable on marginal lands (e.g. halophytes, trees)
  * Restrictions incorporated in policy (RED II : 7% max from “cropland growth”)
* LUC/ILUC, biodiversity challenges with wholesale land conversion
  * Palm-pushback already influencing policy against FOG
  * Also taints all palm, several types of which don’t have the negative aspects of concern in SE Asia
* Perceived need for significant hydrogen for conversion
  * Not the same for all tech; hydrogen can come from biomass itself or other “green sources”
* Purpose-grown lipid feedstocks not ready for primetime
  * Not unprecedented - recent experience with canola

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Multiple lipid conversion processes for SAF

U.S. commercialization activity / intent

HDRD (& SAF?) from lipids/F.O.G.

- Diamond Green: Norco, LA
- REG: Geismar, LA
- World Energy: Paramount, CA
- BP Cherry Point: Blaine, WA (co-processing diesel)
- Expansions: DGD #2 (290 -> 690M); REG Geismar expansion (90 -> 340M) World Energy Paramount (40 -> 305M), DGD #3 Port Arthur, TX (470M)
- Marathon: Dickinson, ND (180+M by Q1'21); Martinez, CA (260M by H2'22, 730M by YE '23)
- Ryze / Phillips 66: Reno & Las Vegas, NV (& 60M)
- Phillips 66: Rodeo, CA (800M eventually, 122M actual from Apr'21)
- Global Clean Energy Bakersfield (105M)
- SG Preston: pivot announcement pending
- NEXT / Shell (575M -> 765M)
- ARA licensing build-out (first 3 activities = 168M)
- HollyFrontier (Cheyenne & Artesia = 200M)
- Texmark HDRD distillation
- Emerald (100M); Steamboat (100M)
- CVR refineries (Wynnewood 100M, from 2021; Coffeyville conversion)
- Greentech Materials; St. Joseph Renewables (90M)
- Multiple conversion evaluations: PBF/Shell (Martinez)
- NWABF, Western WA feasibility study (64M)
- Grön Fuels, Baton Rouge (900M)
- Seaboard Energy, Hugoton (99M)
- Vertex, Mobile [Mobil/Shell LP refinery overhaul] (215M by '23)
- PBF Chalmette, LA refinery, $500M hydrocracker retrofit
- Calumet, Great Falls partial conversion (140M)

In Production: 390+ M gpy Nameplate @ YE '19

In Development: Exceeding 6B gpy capacity by 2026 !?!

Pertinent to aviation interests in 4 ways:

- HFP-HEFA (using HDRD for blending)
- Direct HEFA-stream distillation pivot
- Downstream fractionation/refining, or via co-processing
- Co-development of lipid feedstocks & supply chains

... necessitates serious engagement with purpose grown oilseed & F.O.G. development / expansion

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Lipid multi-generational product plan (MGPP)
Addressing the perceived shortfall of available lipids from FOGs

Expansion

1) **Waste lipid aggregation**
   * Tallows, white grease, chicken fat, yellow grease, brown grease, …
2) **Industrial effluents and byproducts**
   * Tall oil, food processing oils (seafood processing), PFAD/POME, culled nut oils, …
3) **Existing oilseed / row crop expansion**
   * Rapeseed, canola, soy, sunflower, DCO, mustards, …
   * Introduction of multiple cropping concepts (inter-, relay-, dual-, …)
   * Palm (addressing oil palm sustainability issues of SE Asia)

R&DDD

4) **New oilseed / row crops** (with mitigated LUC/ILUC, e.g. winter cover cash crops, rotations/fallows, …)
   * Camelina, **carinata**, pennycress, …
5) **Tree / bush oils** (seed or leaf [e.g. eucalyptus] extraction)
   * Pongamia, coconut, hazelnut, jatropha, macauba (prevalent in tropics and subtropics; India reports 400 species, 10 of specific interest)
6) **Algae – micro, macro** (and more targeted conversion process refinement, e.g. HTL)
   * Bio-derived triglycerides and pure hydrocarbons (e.g. *Botryococcus braunii)*
7) **Advanced microbial conversion of lignocellulose/wastes to precursor molecules** (lipids, fatty acids)
   * Acetogens, oleaginous yeasts, cyanobacteria, fungal, methanogens…
8) **Engineered oil excrescence in biomass itself**
   * E.g. the work of ARPA-E PETRO (similar to crushing sugarcane or sugar beets to release a sugary juice, the crush of a modified tobacco or energy grass could produce a lipid stream)

The prospects for Carinata?

Is the sky the limit?

… hopefully it's inherent in your point of view on SAF!

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Worldwide SAF production capacity forecast

Announced intentions*

Year-end Production Capacity (M gpy)

By YE '21	2022	2023	2024	2025	2026
world energy Paramount	RED ROCK BIOFUELS Lakeview 6	REPSOL Cartagena 20	gevo Net Zero 1 22.5	gevo Speyer 22.5	VELOCYS Altalto Immingham 16
NESTE Porvoo	SkyNRG NORDIC Delfzijl 33	ReadiFuels two locations 24	PHILLIPS 66 Rodeo 290		VELOCYS Bayou Natchez, MS 33
gevo Silsbee	NESTE Singapore 330	NESTE Rotterdam 130	TOTAL Grandpuits 56	IATA reports as much as 1.9B gpy capacity (Waypoint 2050 analysis)	
TOTAL La Mede	LanzaJet Freedom Pines 10	Fulcrum BIOENERGY Gary, IN 21	preem Gothenburg 70		
eni Gela	world energy Paramount+ 150		LanzaJet 3 Int'l locations 90		
Fulcrum BIOENERGY Sierra					
air bp Castellon					
~70+ M	~600+ M	~800+ M	~1,330 M	~1.4 B +	

* Not comprehensive; CAAFI estimates (based on technology used & public reports) where production slates are not specified

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Sourced from CAAFI (Commercial Aviation Alternative Fuels Initiative - see www.caafi.org), 14Mar2021.
Information herein originates from the definitions in ASTM D7566 as well as industrial knowledge emanating from the work of CAAFI and industry practitioners.

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, 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 and iso-butanol 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, Sunshine, 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	2020	**IHI Corporation**	IHI

* The entity who was primarily responsible for pushing the technology through aviation's D4054 qualification is shown in bold.

** There are 3 major systems associated with FT conversion: Gasification, Gas Clean-up, and Fischer-Tropsch Reactor. This column focuses on the FT reactor only. There are over a hundred gasification entities in the world, and several of the major oil companies own and utilize gas clean-up technology. Further, up to the current time, FT reactors were only produced at very large scale. The unique technology brought to the market by Velocys *et al.* is a scaled-down, micro-channel reactor appropriately sized for processing of modest quantities of syngas as might be associated with a biorefinery.