Wisconsin Energy Institute
UNIVERSITY OF WISCONSIN–MADISON

Industry Seminar

Decarbonizing Aviation: Why the focus on SAF?

Sustainable Aviation Fuel

Steve Csonka
Executive Director, CAAFI

CAAFI
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

First flight from continuous commercial production of SAF
UAL 0708, 10 March 2016, LAX-SFO

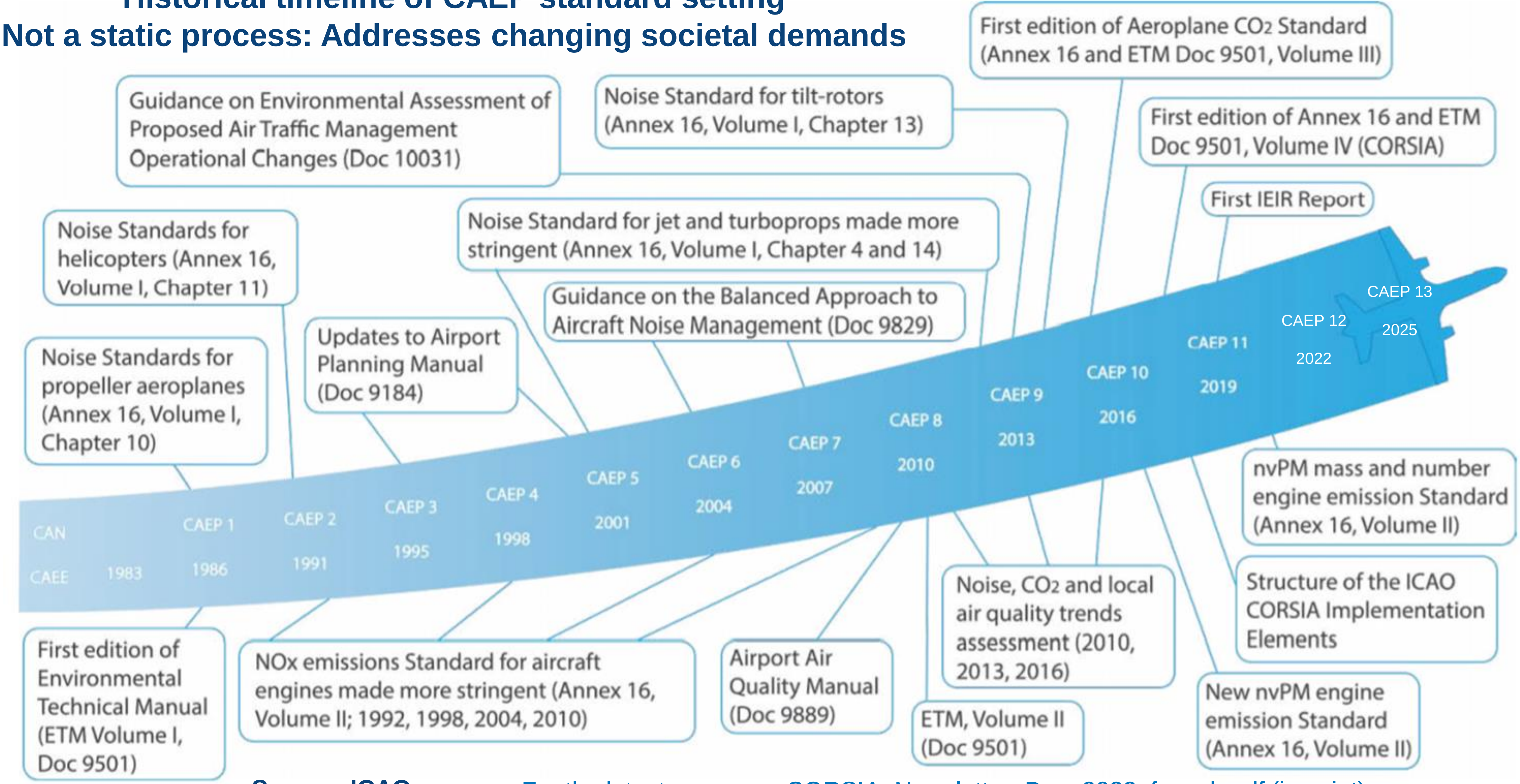
Fuel from World Energy - Paramount (HEFA-SPK 30/70 Blend).

Only U.S. facility offering continuous production of SAF at present.
Other batch production & tolling occurring due to extreme customer interest.

01Feb'23

Aviation takes its environmental responsibility seriously

Historical timeline of CAEP standard setting
Not a static process: Addresses changing societal demands



Source: ICAO

For the latest summary: CORSIA_Newsletter_Dec_2022_forweb.pdf (icao.int)

Aviation takes its environmental responsibility seriously …on GHGs too

The business aviation community has long been committed to reducing the environmental impact of its products and operations. Indeed, we have improved the fuel efficiency of our products 40% over the past 40 years.

PETER J. BUNCE
PRESIDENT AND CEO
GENERAL AVIATION
MANUFACTURERS ASSOCIATION

DONALD SPRUSTON
DIRECTOR GENERAL
INTERNATIONAL BUSINESS
AVIATION COUNCIL

Our manufacturers and operators continually seek new ways of increasing an airplane's performance and range while reducing fuel consumption. Nonetheless, our community recognizes that we must do our part to reduce aviation emissions further even as we grow to meet rising demand for transportation.

The General Aviation Manufacturers Association (GAMA) and the International Business Aviation Council (IBAC), on behalf of the manufacturers and operators of business aviation worldwide, have therefore developed an aggressive strategy for CO_2 emissions reductions to 2050. We also join with the commercial aviation sector in endorsing the International Civil Aviation Organization's (ICAO) proposal for a global sectoral approach for aviation emissions in a post-Kyoto Agreement on climate change.

Our commitments parallel those made by the commercial aviation sector and depend equally on efficiency improvements that are projected from infrastructure modernization, operations and alternative fuels. Our community pledges an average of 2% improvement in fuel efficiency per year from now until 2020 on a fleet-wide basis. We acknowledge the need for appropriately structured market-based measures, so long as any revenues collected are reinvested into the sector. Such measures, along with advances in the areas mentioned above should help business aviation achieve carbon neutral growth by 2020 and an absolute reduction of 50% of CO_2 emissions by 2050 relative to 2005.

Business aviation is a vital tool for businesses and economic development and is an integral part of the international transportation system. It facilitates commerce and investment, connects people and communities around the globe, helps relieve famine, and delivers vital relief to those in need or afflicted by natural or man-made disasters. Business aviation also represents a dynamic and critical engine for economic growth that brings jobs and prosperity to millions of people worldwide.

While business aviation manufacturers and operators are engaged in a sustained effort to meet these targets, a strong partnership between industry and government is also absolutely necessary to achieve these goals. We can only meet these targets if all stakeholders work together on comprehensive, ambitious and fair worldwide action to mitigate emissions.

In this document, we describe our strategy and ambitious goals to meet this critical global challenge of emissions reduction while continuing to deliver vital economic, business and social benefits.

enviro.aero

Aviation Industry Commitment to Action on Climate Change

As leaders of the aviation industry, we recognise our environmental responsibilities and agree on the need to:

- build on the strong track record of technological progress and innovation that has made our industry the safest and most efficient transport mode; and
- accelerate action to mitigate our environmental impact, especially in respect to climate change while preserving our driving role in the sustainable development of our global society.

Therefore, we, the undersigned aviation industry companies and organisations declare that we are committed to a pathway to carbon-neutral growth and aspire to a carbon-free future.

To this end, in line with the four-pillar strategy unanimously endorsed at the 2007 ICAO Assembly, we will:

1. push forward the development and implementation of new technologies, including cleaner fuels;
2. further optimise the fuel efficiency of our fleet and the way we fly aircraft and manage ground operations;
3. improve air routes, air traffic management and airport infrastructure; and
4. implement positive economic instruments to achieve greenhouse gas reductions wherever they are cost-effective.

We urge all governments to participate in these efforts by:

1. supporting and co-financing appropriate research and development in the pursuit of greener technological breakthroughs;
2. taking urgent measures to improve airspace design including civil/military allocation, air traffic management infrastructure and procedures for approving needed airport development; and
3. developing and implementing a global, equitable and stable emissions management framework for aviation through ICAO, in line with the United Nations roadmap agreed in Bali in December 2007.

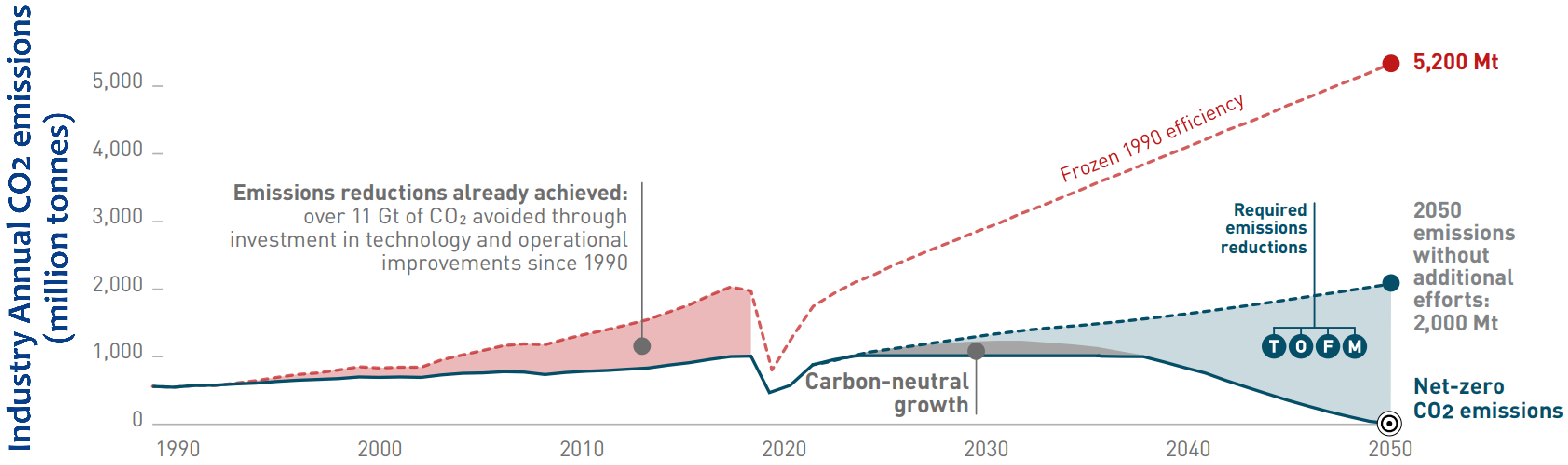
Our efforts and commitment to work in partnership with governments, other industries and representatives of civil society will provide meaningful benefits on tackling climate change and other environmental challenges.

We strongly encourage others to join us in this endeavour.

Industry commitments: 2008, 2012, 2015, 2019, 2022

Becoming the first industrial sector to commit to an agreed carbon reduction approach

Civil Aviation current commitment on CO_2 reductions



T Technology, including radical new
O Operations and Infrastructure
F Sustainable Aviation Fuels
M Market-based measures

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Courtesy of ATAG: https://aviationbenefits.org/media/167417/w2050_v2021_27sept_full.pdf

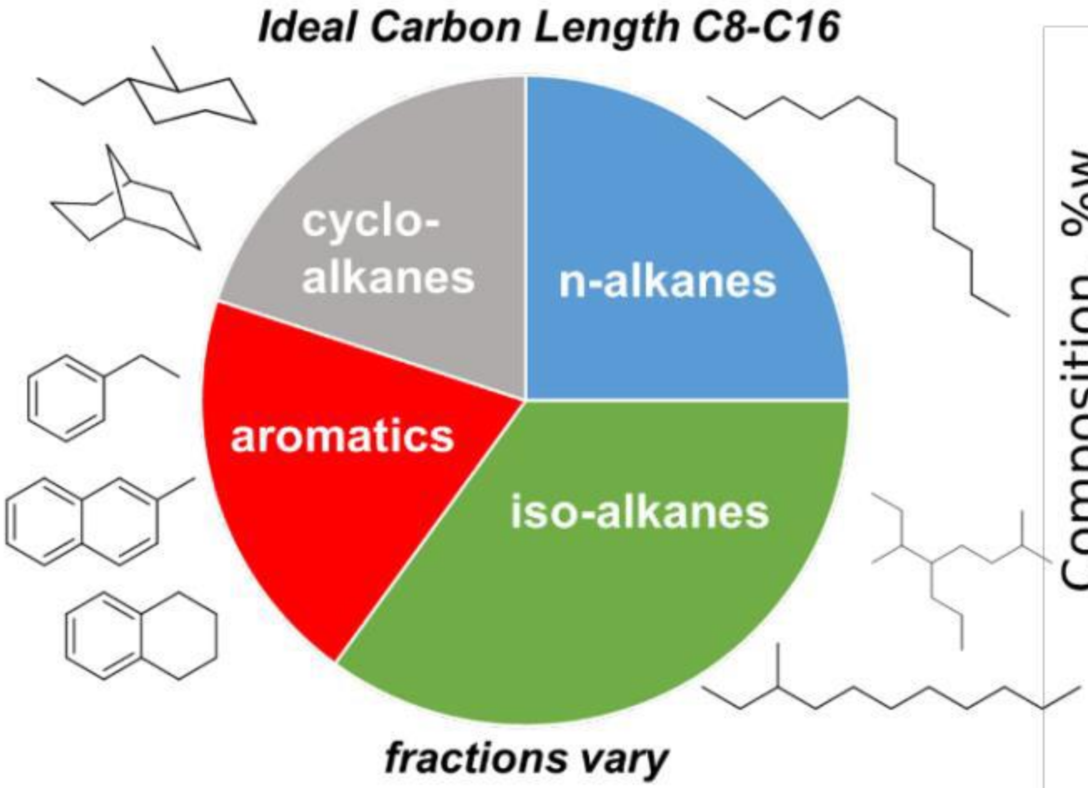
SAF (Sustainable Aviation Fuel)
a.k.a. aviation biofuel, biojet, synthetic aviation turbine fuel

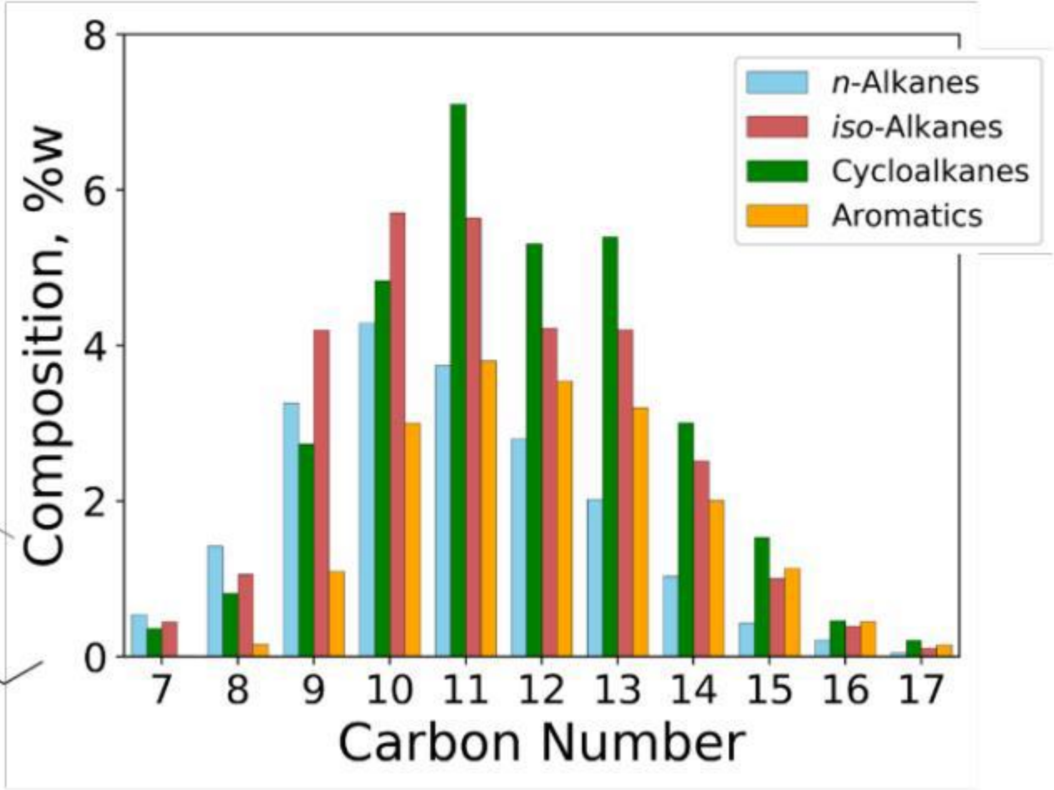
Aviation Fuel: Maintains the certification basis of today's aircraft and jet (gas turbine) engines by delivering the properties of ASTM D1655 – Aviation Turbine Fuel – enables drop-in approach – no changes to infrastructure or equipment, obviating incremental billions of dollars of investment

Sustainable: Doing so while taking Social, Economic, and Environmental progress into account, especially addressing GHG reduction. LCA analysis shows SAF can result in significant net carbon release.

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). Unabashedly - Lowest societal-impact way to decarbonize civil aviation!!

Typical jet fuel chemical composition





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

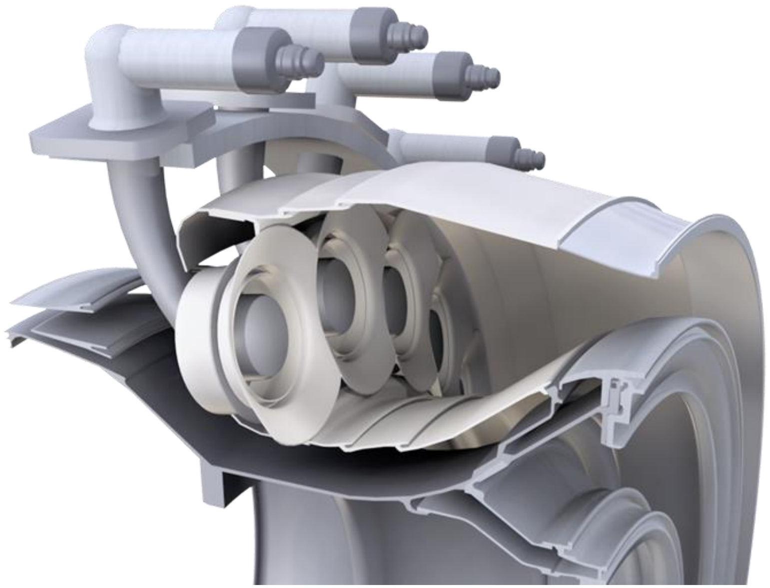
CAAFI
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

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

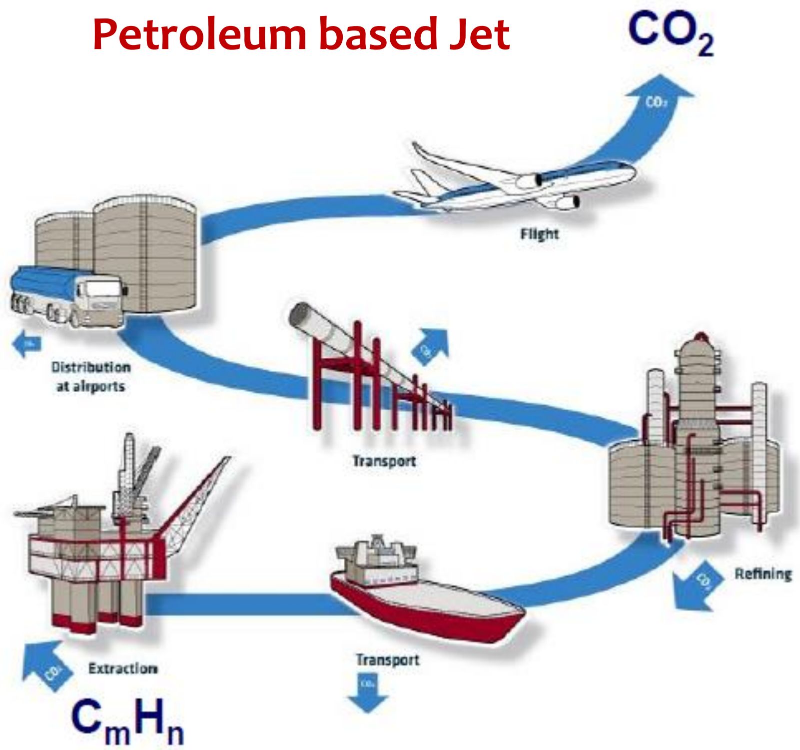
Turbine fuel used for multiple purposes (including for non-turbine use)

…So, its formulation/production must be carefully controlled to get the right fit-for-use properties

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

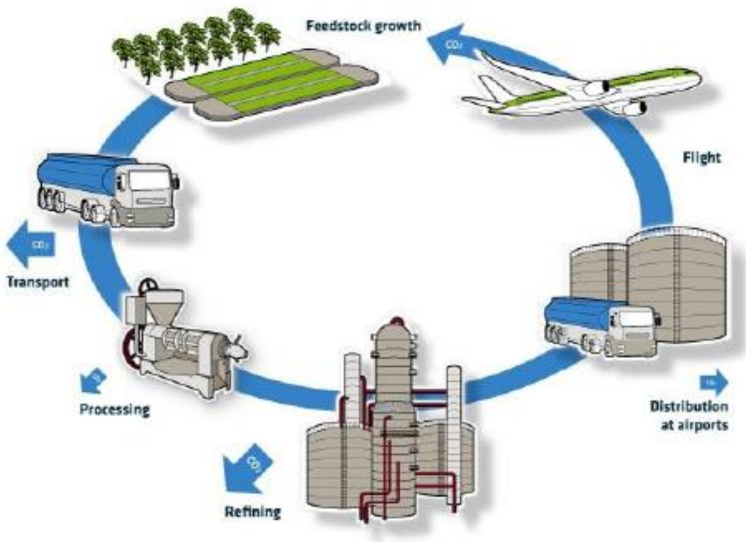
Achieving net Lifecycle GHG Reductions with SAF

Petroleum based Jet



Continuing to pull additional carbon from the ground and releasing it into the atmosphere as CO_2

Sustainable Aviation Fuel

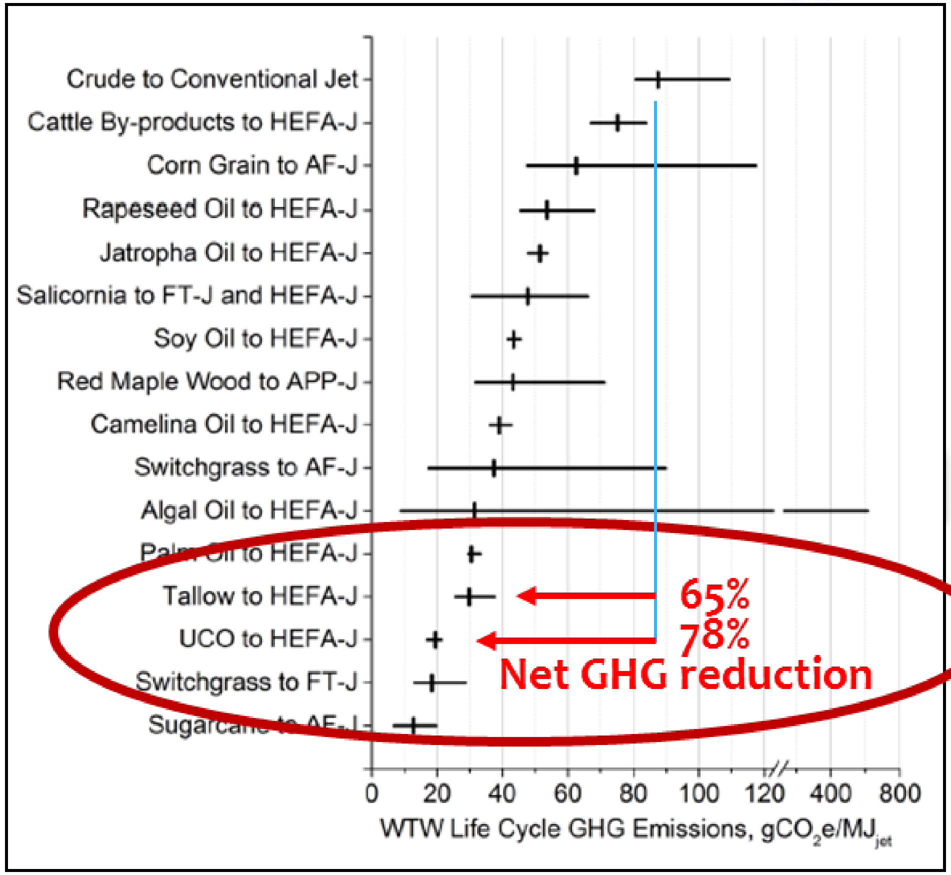


Acquiring the majority of our carbon from the atmosphere, via biology or recycling, and turning it back into fuel

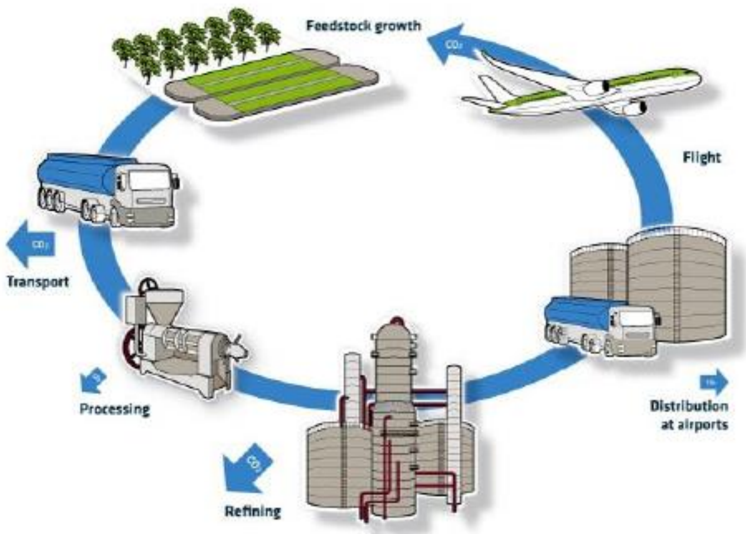
Result is a net reduction of additional GHG (CO_2) being introduced into our biosphere.

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Achieving net Lifecycle GHG Reductions with SAF



Sustainable Aviation Fuel



Acquiring the majority of our carbon from the atmosphere, via biology or recycling, and turning it back into fuel

- **Policy rewards reductions >50%**
- **Many solutions in the 60-80% range**
- **Some solutions achieve >100% via carbon sequest'n or other emission reduction**

CAAFI
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Majority of CO_2 emissions come from medium- and long-range flights, and larger aircraft

Global CO_2 emissions from aviation – 2018, in % of total CO_2 emitted

Aircraft Type [UAV, UAM, GA, Feeder]	Flight Range Category (km) 0-500	501-1000	1001-2000	2001-3000	3001-4500	>4500	Total Share CO_2 Emissions	Global Fleet
Commuter <19	<1%						<1%	4%
Regional 20-80	1.2%	1.2%	0.8%	0.1%			[illegible]	[illegible]
Short Range 81-165	1.6%	5.8%	10.1%	4.0%	2.0%		[illegible]	[illegible]
Med. Range 166-250	1.1%	4.9%	13.1%	8.4%	6.9%	8.5%	43%	[illegible]
Long Range >250	0.1%	0.5%	1.6%	1.6%	1.9%	24.2%	30%	12%
Total	~4.5%	~12.4%	~25.6%	~14.1%	~10.7%	~32.7%		

Hybridization, electrification, fuel switching, … to start in this space

Technology needed for large aircraft electrification or H_2 not viable for decades, without major paradigm changes!

Source: World Economic Forum – Mission Possible Platform, DiioMi

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

SAF is projected to be critical to meeting Aviation Climate Goals through and beyond 2050

	2020	2025	2030	2035	2040	2045	2050
Commuter » 9-50 seats » <60 minute flights » <1% of industry CO_2	SAF	Electric and/or SAF	Electric and/or SAF	Electric and/or SAF	Electric and/or SAF	Electric and/or SAF	Electric and/or SAF
Regional » 50-100 seats » 30-90 minute flights » ~3% of industry CO_2	SAF	SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF	Electric or hydrogen fuel cell and/or SAF
Short-haul » 100-150 seats » 45-120 minute flights » ~24% of industry CO_2	SAF	SAF	SAF	SAF	Electric, hydrogen combustion and/or SAF	Electric, hydrogen combustion and/or SAF	Electric, hydrogen combustion and/or SAF
Medium-haul » 100-250 seats » 60-150 minute flights » ~43% of industry CO_2	SAF	SAF	SAF	SAF	SAF	SAF	SAF potentially some Hydrogen
Long-haul » 250+ seats » 150 minute + flights » ~30% of industry CO_2	SAF	SAF	SAF	SAF	SAF	SAF	SAF

Ref: ATAG – Waypoint 2050 Report

"SAF &" remains our primary means of decarbonizing aviation

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Aviation is committed to the use of SAF

- Airline commitment at Sep’21 IATA/ATAG Forum: NZC by 2050, with a focus on SAF
- Further commitments to 10% SAF usage by 2030
  - A4A & US Government Grand Challenge Announcement, 09Sep’21
  - 60 companies in Clean Skies for Tomorrow program (IAG, oneworld, …), 22Sep’21

3 B gpy by 2030
35 B gpy by 2050

- Business Aviation similar commitments at Oct’21 NBACE
- Offtake committed for SAF production slates from first 7+ refineries, 5–15 years
- CORSIA incorporates SAF: new LTAG of NZC by 2050, new baseline (2019-15%)
- Countries now adopting additional targets and policy approaches for domestic SAF usage (RFS, LCFS, tax policy), including SAF blending mandates in the EU
- Aviation also interested in carbon abatement via adjacent tech: PtL, BECCS, DACCS
- OEMs and DOD continuing R&D, evaluating acquisition options

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

How SAF is made? – via "Approved Pathways"

1 Feedstocks (sourcing H & C)
- Lipids
- Lignocellulose
- Starches / Sugars
- Waste streams
- Circular economy byproducts

→

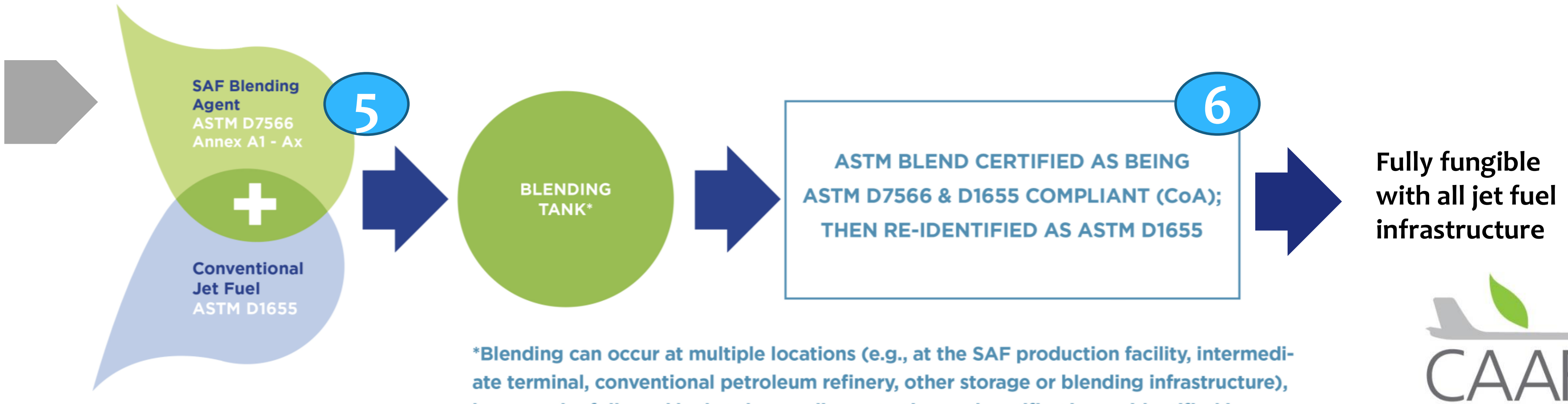
2 Conversion Processes
- Biochemical (microbes, e.g. fermentation)
- Thermochemical (heat, pressure, catalysts)

→ **Biocrude** →

3 Refinery Processes
- Hydrotreament
- Hydrocracking
- Hydroisomerization
- Distillation

→ **C7-C17 pure HC suitable for jet** →

4 SAF Blending Agents: ASTM D7566 Annex A1 - Ax



*Blending can occur at multiple locations (e.g., at the SAF production facility, intermediate terminal, conventional petroleum refinery, other storage or blending infrastructure), but must be followed by batch compliance testing and certification as identified in D7566 and D1655.

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

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, 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 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, 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	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.

SAF progress - Technical

SAF are becoming increasingly technically viable

* Aviation now knows we can utilize numerous production pathways
  * 7 approved, 6 in-process, >15 in pipeline
  * 4 pathways have approval to go to ballot in 2023, pending OEM review finalization
* Enabling use of all major sustainable feedstocks

  (lipids, sugars, lignocellulose, hydrogen & carbon sources, circular-economy byproduct streams)
* Utilizing thermo-chemical and bio-chemical conversion processes to produce pure hydrocarbons, followed by standard refinery processes
* Following blending with petro-jet, SAF is drop-in, indistinguishable from petro-jet
* Some future pathways expected to produce SAF blending components that will need less, or zero, blending
* Continuing streamlining of qualification – time, $, methods
* Expanding exploration of renewable crude co-processing with refineries

Co-processing:

Blending bio-crude liquids with petroleum streams at various points in an existing refinery to produce fuels with lower carbon intensities

- Viewed as way to achieve significant scale more quickly …
  - Without CapEx burden of stand-alone biorefineries
  - Leveraging existing distribution infrastructure; foregoing need for SAF blending
- Caution: renewable carbon in finished fuel products not uniformly distributed
- Definitions added to ASTM D1655, *Annex A1. FUELS FROM NON-CONVENTIONAL SOURCES*
  - Two existing Co-processing pathways
    - 5% v/v F.O.G. (to enable HDRD production (e.g. BP Cherry Point))
    - 5% v/v FT biocrude (plan for Fulcrum at Marathon Anacortes)
  - Three new Task Forces
    - Use of pyrolysis oil from tire deconstruction – P66
    - Increasing v/v limits (perhaps to 30%) – BP
    - Use of HVO (perhaps at 40%) & re-refining of slop/transmix/off-spec – Exxon Mobil

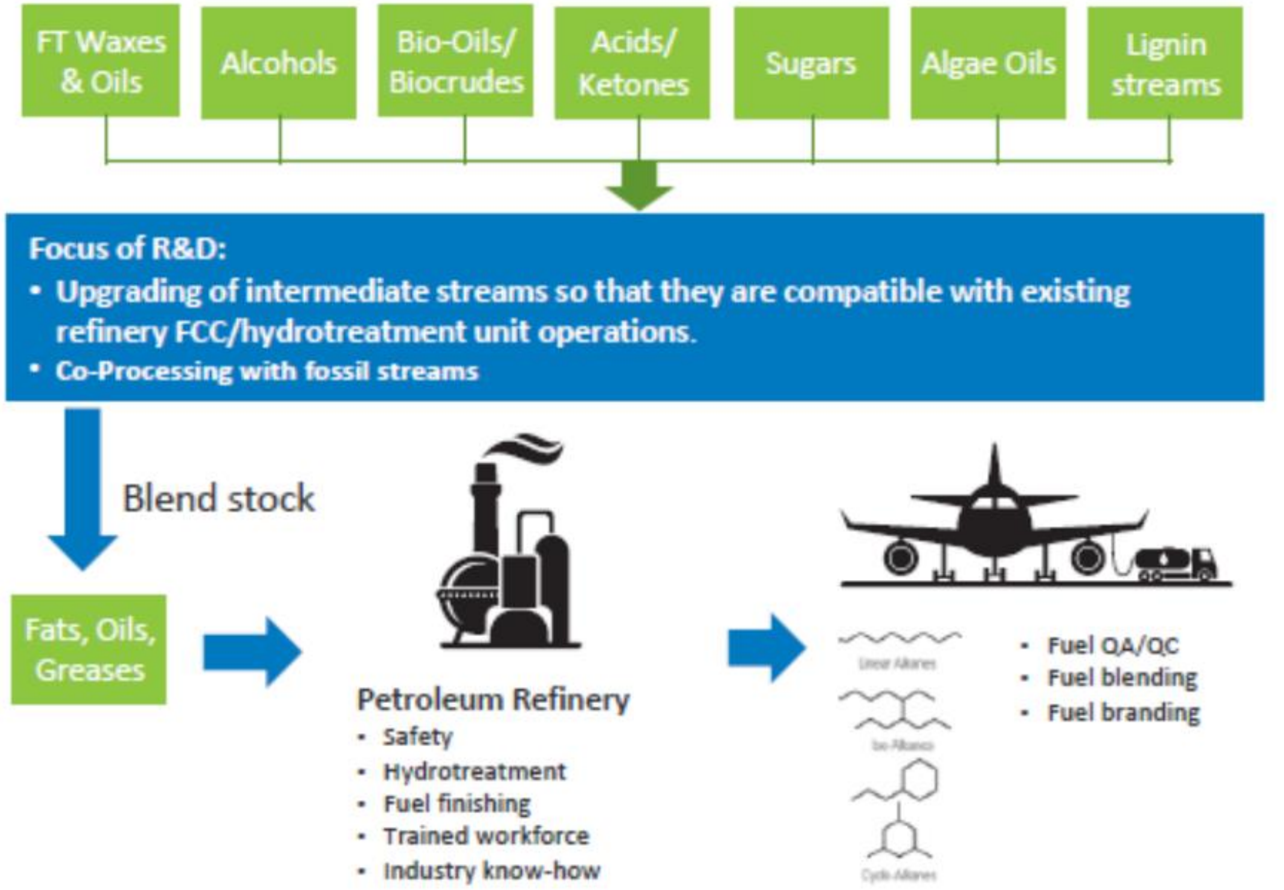
Producing SAF Using Biointermediates

Opportunities

- ~6.6M BBPD (97 BGPY) distillate HT capacity available in the United States
- Leveraging this capacity may save capital costs
- May allow incremental transition to renewables by blending renewable and fossil streams
- Opportunities where re-permitting may not be required

Challenges

- Large variability of streams
- Match equipment to streams
- Hydrotreater scale too large
- ASTM approval of pathways
- Incompatibility of materials of construction with bio-streams
- Managing exothermic reactions



https://www.eia.gov/dnav/pet/PET_PNP_CAP1_A_(NA)_8CDHD0_BPSD_A.htm

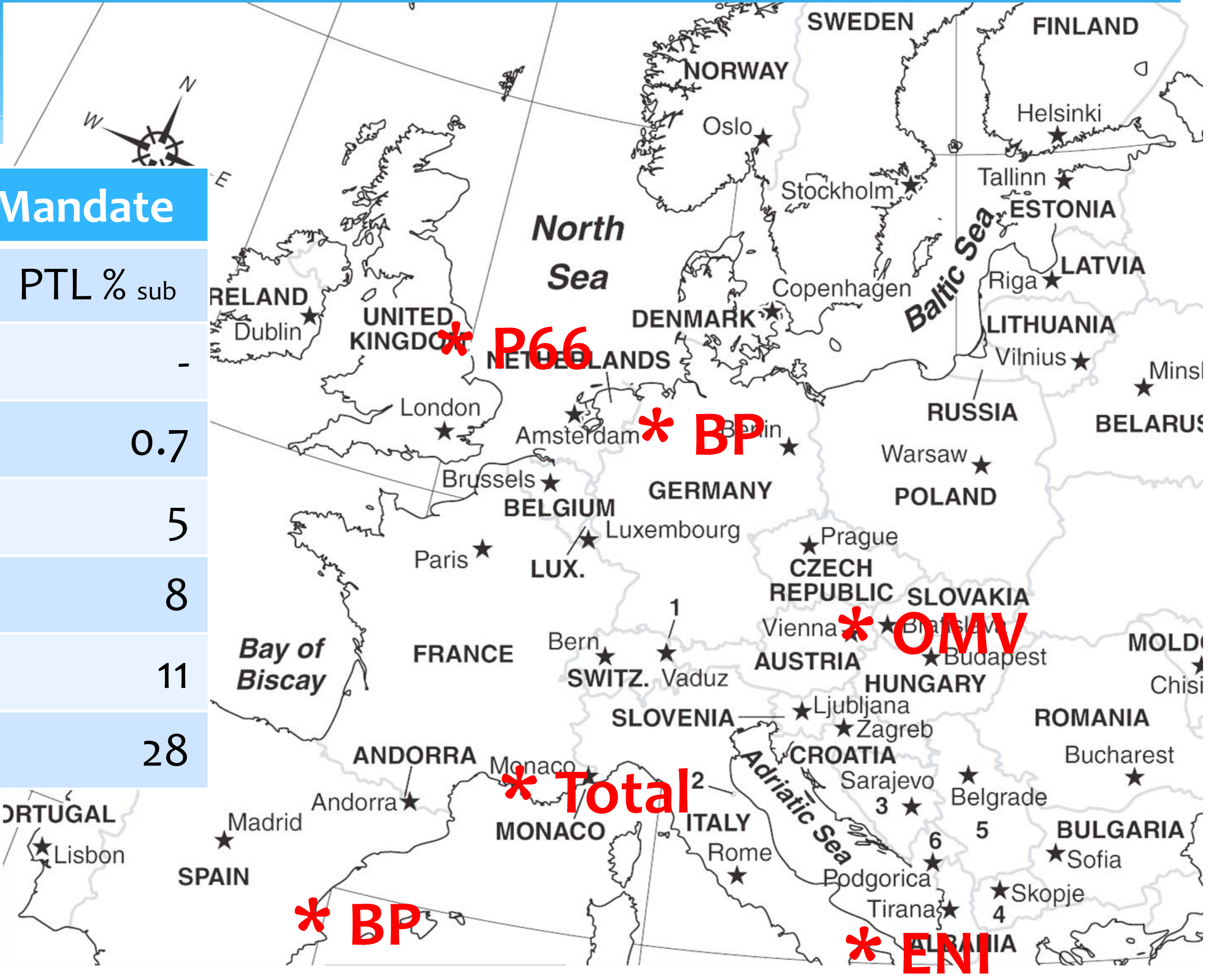
NREL

COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Co-processing of SAF:

- Significant '21-'22 trials in EU to address:
  - Blending mandates in place for Sweden, Norway, France @ 1% blending
  - Preparation for 'Fit for 55' EU SAF Blending Mandate ⇨
  - UK proposed blending mandate:
    - 10% by 2030, and 75% by 2050
- Part of ambition for refiners to be net-zero companies themselves (production and products)

EU Proposed Mandate		
Year	SAF %	PTL % sub
2025	2	-
2030	5	0.7
2035	20	5
2040	32	8
2045	38	11
2050	63	28



* Select EU co-processing trials

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

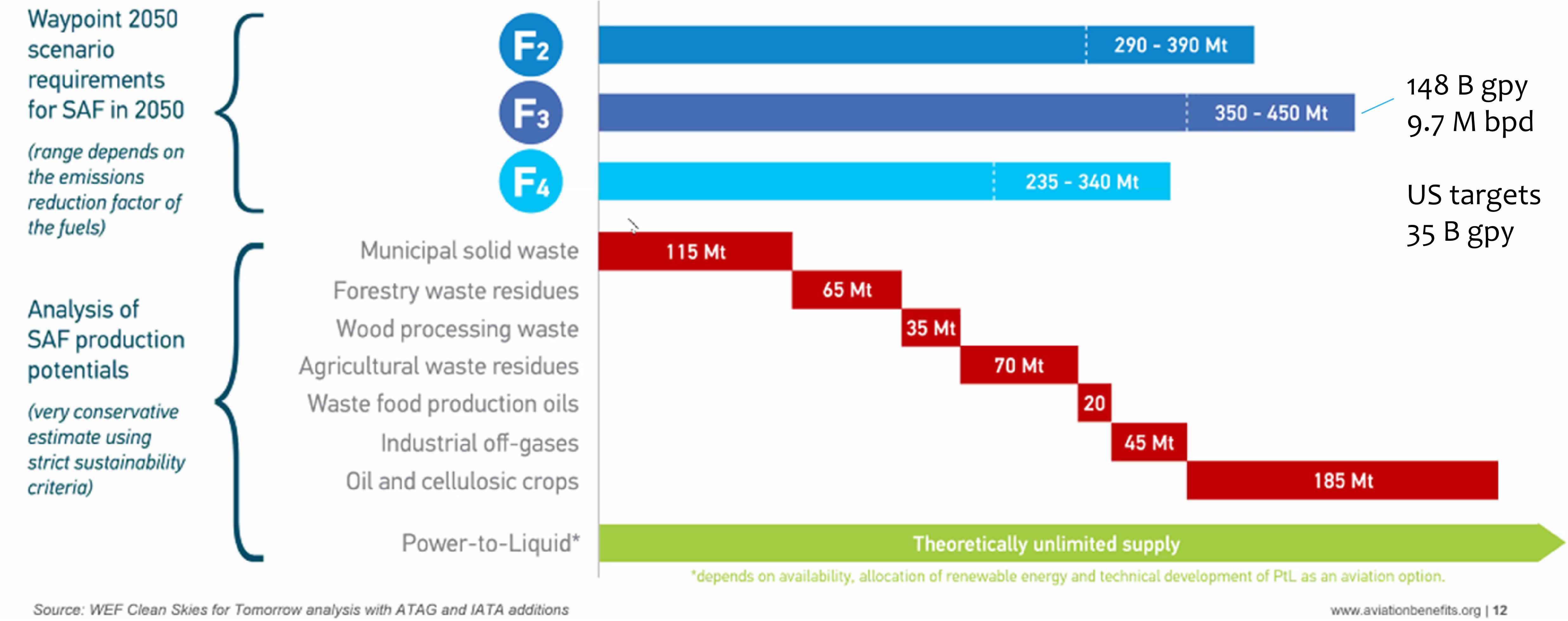
Promising emerging technologies / feedstocks

* Those that lower cost or increase value of total production slate
  * Higher carbon utilization from feedstocks
  * Lower CapEx and/or Lower OpEx – enabling use of low-cost, plentiful, 24x7 supply
  * Integrated systems
  * Finding higher value for production slip streams or byproducts
  * Capturing value from other environmental services
  * Driving to ultra low CI scores to increase value from rewarding policy
* Steady stream of low TRL examples for the above
* In some other cases, difficult to envision near-term tangible progress

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

SAF-production-potential outlook: 2050

Targets of opportunity with low ILUC and affordability

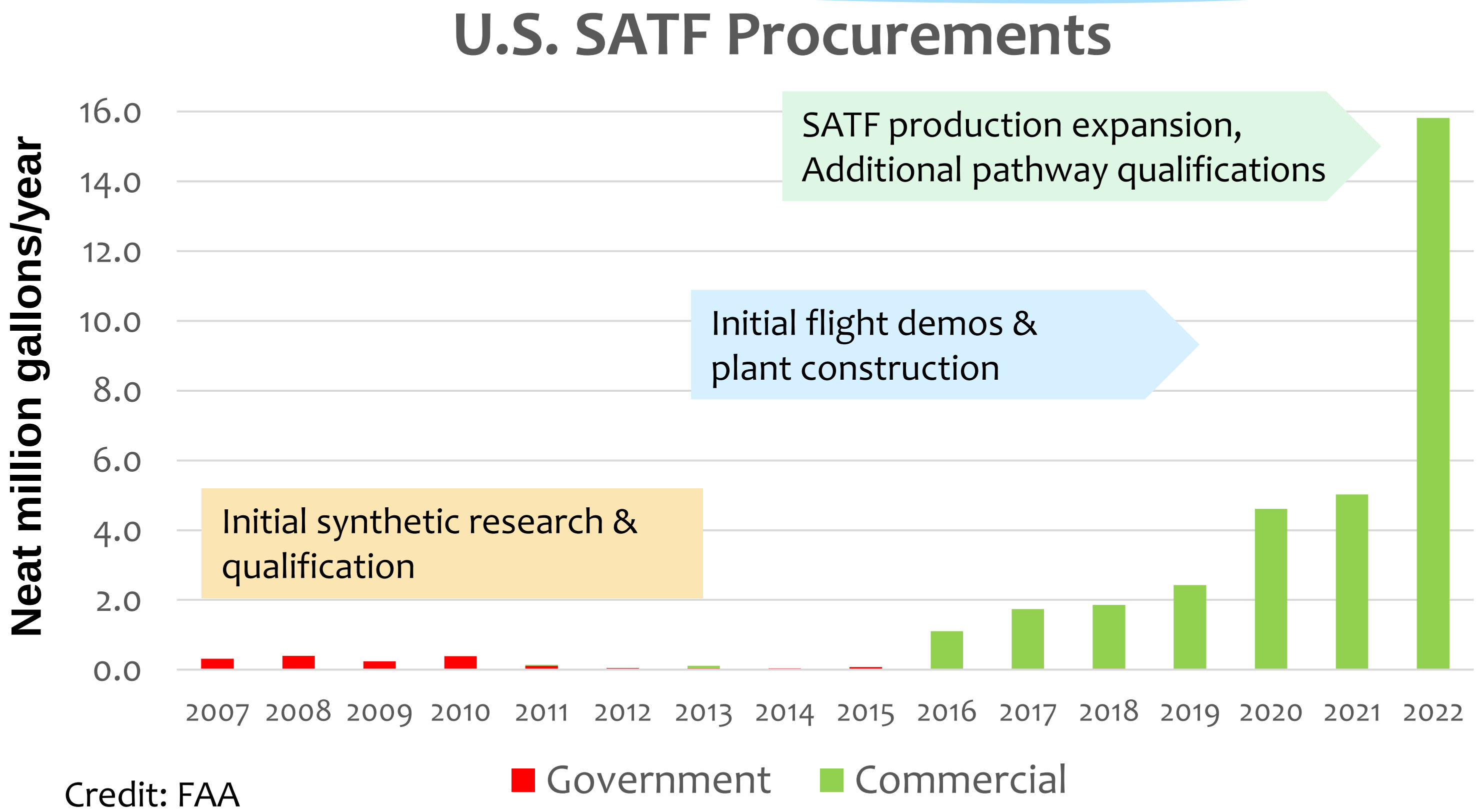


148 B gpy
9.7 M bpd

US targets
35 B gpy

Where we stand on U.S. SAF consumption
Initiation underway, still early

- Seven years of sustained commercial production and use
- Commercial & General Aviation engaged
- Two facilities in operation, several others in physical construction
- Cost delta still a challenge, with practicalities favoring renewable diesel
- Worldwide: Growing number of entities produced ~80M usg SAF in 2022 – Finland's Neste the market leader



Credit: FAA
*Reflects voluntarily reported data on use by U.S. airlines, U.S. government, manufacturers, other fuel users, and foreign carriers uplifting at U.S. airports.
^2017-2021 calculation includes reported EPA RFS2 RINs for jet fuel.
2022 data as of September 2022

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

U.S. SAF production forecast

Announced intentions, neat*

Est. Year-end Production (M gpy)

~15 M

By YE '23 (~55 M)
- LanzaJet Freedom Pines 10
- Montana Renewables Great Falls 30

2024 (~450 M)
- gevo Net Zero-1 SD 55
- Phillips 66 Rodeo 290
- AEMETIS Carbon Zero #1 Riverbank 22
- Montana Renewables Great Falls' +30

2025 (~992 M)
- Diamond Green Diesel Port Arthur 235
- world energy Paramount B 250
- USA BioEnergy (Renewable Energy Solutions) Bon Wier, TX 26
- Fulcrum Bioenergy Centerpoint 31

2026 (~1,415 M)
- AEMETIS Carbon Zero Riverbank+ 22
- LanzaJet Hennepin 120
- world energy Houston 250
- Fulcrum Bioenergy Trinity 31

2027 (~1,445 M)
- SkyNRG Americas NW #1 30

2028 (~1,470 M)
- Velocys Bayou Natchez, MS 25

Unannounced or In-development efforts:
- 160+ additional new-entrants collaborating with CAAFI
- Outlined expansion goals of: LanzaJet, Gevo, Alder, Fulcrum, …
- Refinery co-processing / conversion
- Renewable Diesel switching pending BTC/PTC evaluation

Exact Timing & Production tbd

- 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.
- Does not include fractions of substantial Renewable Diesel capacity (existing and in-development) that can be shunted to SAF based on policy support

Steve Csonka
Executive Director, CAAFI
+1-513-800-7980
Csonka.CAAFI.ED@gmail.com
Steve.Csonka@caafi.org
www.caafi.org
info@caafi.org

CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

SAF Grand Challenge (SGC)

All of gov. approach to enable: 10% neat SAF usage by 2030, 100% by 2050

- Execution Roadmap V1.0 released on 23Sep'22
- Execution via multiple mechanisms, likely matrixed workstreams, via 6 key foci
  - Feedstock Innovation
  - Conversion Technology & Processes
  - Building Regional Supply Chains
  - Policy and Valuation Analysis
  - Enabling End Use
  - Communicating Progress & Building Support

Activity has transitioned to defining work teams, leadership, operating norms, inventorying current activities and funding, …

- The expanded approach outlined by the SGC is not fully funded at present. The IRA addresses some opportunities. So, efforts will likely be needed in subsequent budgets (various DOE Offices, FAA AEE, USDA Farm Bill, …), requiring industry advocacy.
- Some efforts already underway – e.g. LCA Interagency Working Group

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

SGC execution examples
Specific applicability to SAF

1. DOE Award: BETO Scale-Up and Conversion, $64.7M over 22 projects
2. DOE FOA: Waste Feedstock & Conversion, $34.5M, LOI 18Apr’22, Full Appl. 07Jun’22
3. USDA Award: Climate Smart Commodities, $2.8B+, 70+ projects, 2 tranches, 14Sep’22
4. USDA RFA: NIFA/AFRI SAS CAPs, $80M, projects to $10M, LOI 27Apr’22
5. DOE/SC/BER FOA: Biosystems Design … Biofuels, $1-5M for 6-12 projects
6. RFI: Biomass Conversion R&D and Analysis
7. RFI: Community-Scale Resource and Energy Recovery from Wastes
8. RFI/NOI: BETO Scale-Up and Conversion, initial FOA pending
9. DOE BERC Renewals: 2 of 4 centers have SAF-specific thrusts
10. DOT funding in IRA (FAST-SAF, FAST-Tech, RFI imminent, 14Dec workshop)

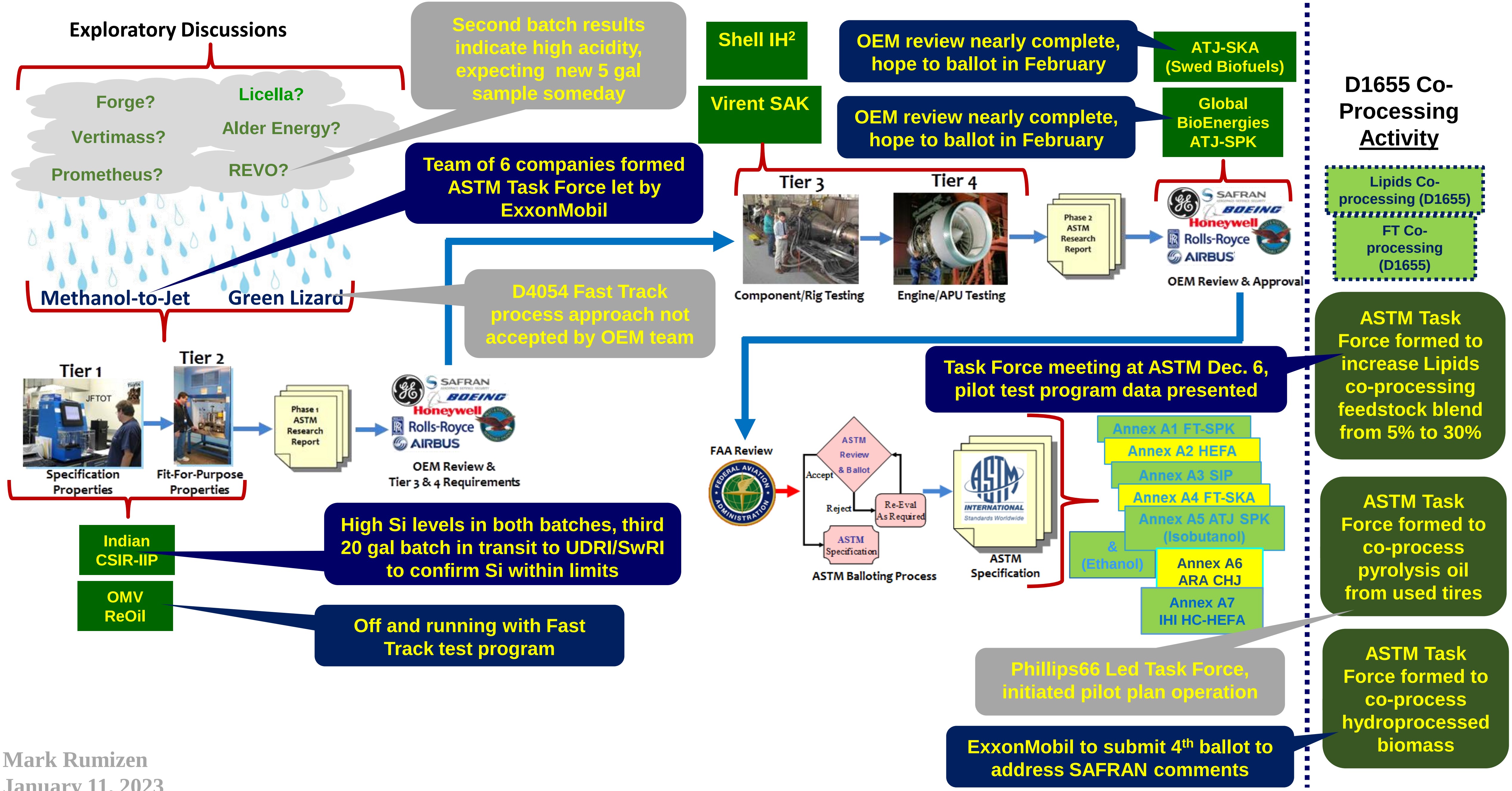
Of course … there are contrarian views

2022 Proposals:

* French Green Party leader Julien Bayou called for a complete ban on business jets last week. However, French government spokesperson Olivier Véran said a total ban is not in the cards during an interview with France Inter radio earlier this week, but added that "restrictions on private jets would signal that the same rules apply to all."
* Renewed calls in EU to ban flights under 2.5 hours in favor of travel by rail. France adopts partial approach.
* From ICCT: A frequent flying levy could generate, from only 2% of the world's population, 81% of the revenue needed to decarbonize aviation … a flat, per-flight air passenger duty (APD) at $25, and a frequent flying levy (FFL) that increases with each flight taken in a year (from $9 to $177). The FFL is designed to place an escalating tax burden on people who fly frequently.

CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

ASTM D4054 Alternative Jet Fuel Qualification Status



Mark Rumizen
January 11, 2023

The BIG issue: achieving sustainability

ICAO document - CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels

USA	Switchgrass (herbaceous energy crops)		10.4	-3.8	6.6
Global	Switchgrass (herbaceous energy crops)		10.4	5.3	15.7

Table 2. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels produced with the Hydroprocessed Esters and Fatty Acids (HEFA) Fuel Conversion Process

Region	Fuel Feedstock	Pathway Specifications	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Global	Tallow		22.5	0.0	22.5
Global	Used cooking oil		13.9		13.9
Global	Palm fatty acid distillate		20.7		20.7
Global	Corn oil	Oil from dry mill ethanol plant	17.2		17.2
USA	Soybean oil		40.4	24.5	64.9
Brazil	Soybean oil		40.4	27.0	67.4
Global	Soybean oil		40.4	25.8	66.2
EU	Rapeseed oil		47.4	24.1	71.5
Global	Rapeseed oil		47.4	26.0	73.4
Malaysia & Indonesia	Palm oil	At the oil extraction step, at least 85% of the biogas released from the Palm Oil Mill Effluent (POME) treated in anaerobic ponds is captured and oxidized.	37.4	39.1	76.5
Malaysia & Indonesia	Palm oil	At the oil extraction step, less than 85% of the biogas released from the Palm Oil Mill Effluent (POME) treated in anaerobic ponds is captured and oxidized.	60.0	39.1	99.1
Brazil	Brassica carinata oil	Feedstock is grown as a secondary crop that avoids other crops displacement	34.4	-20.4	14.0
		Feedstock is grown as a			

With focus on net GHG LCA reductions

* Petro-jet baseline = 89 gCO_2e/MJ
* CORSIA requires >10% reduction (<80.1)
* Many airlines are committing to 50%+ reductions (<44.5)
* To achieve 2050 goals, reductions will need to approach 100%, with some achieving carbon negativity