SAF Technical Certification

Second Phase of the ICAO Assistance Project with the EU Funding :
"*Capacity Building for CO_2 Mitigation from International Aviation*

3 to 5 April 2023
Harare, Zimbabwe

Bruno Silva
Environment Officer, ICAO

Objective

Provide an understanding of the specifications of Aviation Turbine Fuels, and on the process to approve new pathways for its production and use on aircraft.

ACT SAF
Assistance, Capacity-building and Training for SAF

1. Aviation Fuels Terms and Acronyms

Aviation Fuels Terms and Acronyms

ATF = **Aviation Turbine Fuel** also known as JET Fuel

SATF = **Synthetic Aviation Turbine Fuel in the context of ATF specifications** *(e.g. ASTM D1655, DEF STAN 91-091)*
- SATF can be either semi-synthetic (e.g. 50% SBC) or fully-synthetic (i.e. 100% SBC)

SBC = **Synthetic Blend Component** *(e.g. ASTM D7566, DEF STAN 91-091)*

SAF = **Sustainable Aviation Fuel** is defined as a *"renewable or waste-derived aviation fuel that meets the CORSIA Sustainability Criteria"*
(Ref ICAO SARPs Annex 16 Volume IV)

SAF = SATF + Sustainability

LCAF = **Lower Carbon Aviation Fuel**
- Is defined as *"a fossil based aviation fuel that meets the CORSIA Sustainability Criteria"*

(Ref ICAO SARPs Annex 16 Volume IV)

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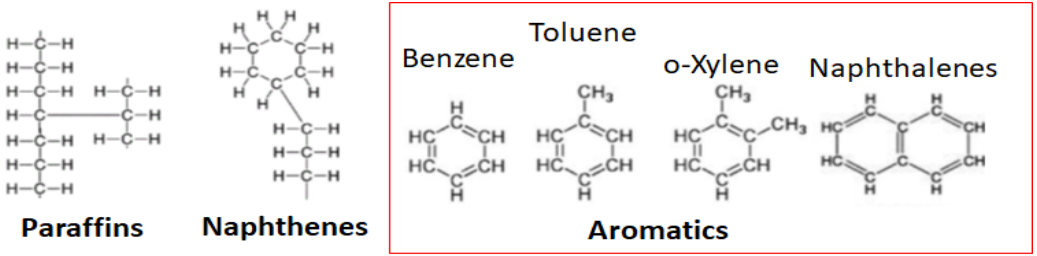
2. What is Aviation Turbine Fuel (ATF)?

What is ATF

What is Aviation Turbine Fuel?

- ATF is a liquid Hydrocarbon in the C_9 to C_{16} range.
- ATF does not have a precise chemical composition but is controlled by property requirements.
- Normally ATF is composed of paraffins, naphthenes & aromatics



DEF STAN 91-091 Issue 14

Table 1 - Test Requirements

Test	Property	Units	Limits	Method
1	Appearance			
1.1	Visual Appearance		Clear, bright and visually free from solid matter and undissolved water at ambient fuel temperature	Visual (see **Annex F.1**)
1.2	Colour		Report	ASTM D156 or ASTM D6045 (see **Note 1**)
1.3	Particulate Contamination, at point of manufacture	mg/l	Max 1.0	IP 564 / ASTM D5452 (see **Note 2**)
or				
1.4	Particulate, at point of manufacture, cumulative channel particle counts	Individual channel counts & ISO Code	Channel Counts / ISO Code	565 or IP 577 (see **Notes** and 3)
1.4.1	≥ 4 µm(c)		R / Max 1	
1.4.2	≥6 µm(c)		Report / Max	
1.4.3	≥14 µm(c)		R / M	
1.4.4	≥21 µm(c)		Report / R	
1.4.5	≥25 µm(c)		Report / R	
1.4.6	≥30 µm(c)		Report / Max 13	
2	Composition			
2.1	Total Acidity	mg KOH/g	Max 0.0	IP 354 / ASTM D3242
2.2	Aromatic Hydrocarbon Types			
2.2.1	Aromatics	% v/v	Max 25.0	IP 156 / ASTM D1319 (see **Note 4**)
or				
2.2.2	Total Aromatics	% v/v	Max 26.5	IP 436 / ASTM D6379 (see **Note 5**)
2.3	Sulfur, Total	% m/m	Max 0.30	IP336
2.4	Sulfur, Mercaptan	% m/m	Max 0.0030	IP 342 / ASTM D3227 (see **Note 6**)
or				
2.5	Doctor Test		Doctor Negative	IP 30
2.6	Refining Components, at point of manufacture			(see **Note 7**)
2.6.1	Non-Hydroprocessed Components	% v/v	Report	
2.6.2	Severely Hydroprocessed Components	% v/v	Report	
2.6.3	Synthetic Components	% v/v	Report, For limits see **Annex B**	(See **Note 8** and **Annex B**)

TABLE 1 Test Requirements

Continued on page 2-7

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3. How is Aviation Turbine Fuel (ATF) produced & controlled?

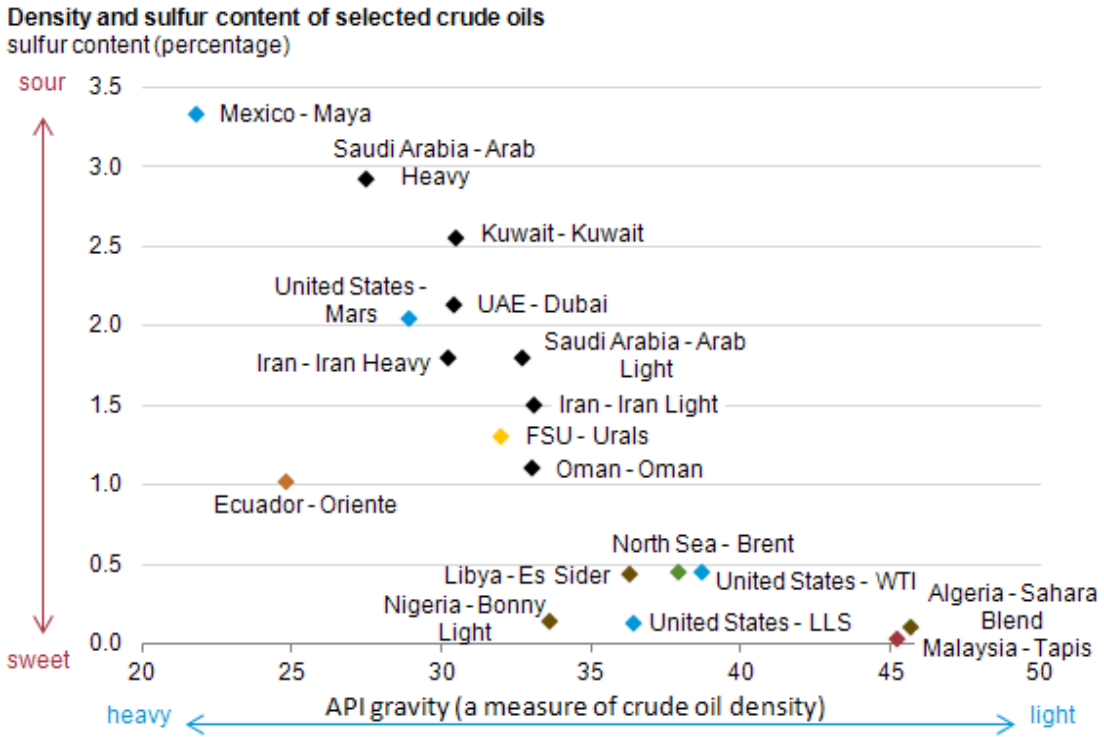
How is ATF produced and controlled

Aviation Turbine Fuel has traditionally been produced from petroleum crude oils

A selection of various crude oils that can be transformed into JET Fuel

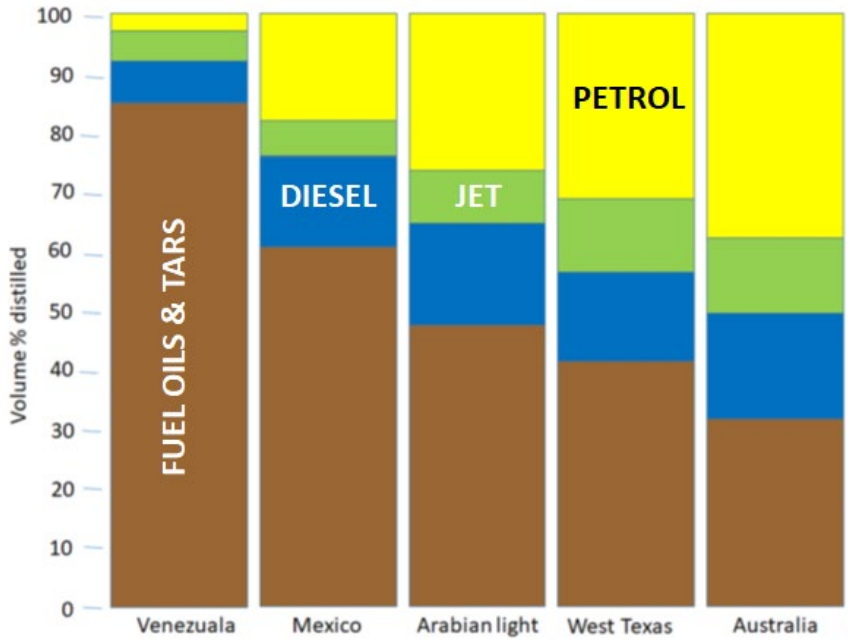
How is ATF produced and controlled

ATF is produced from various different feedstocks and transformed by numerous chemical processes.



Crude oils have different properties depending on where they are from

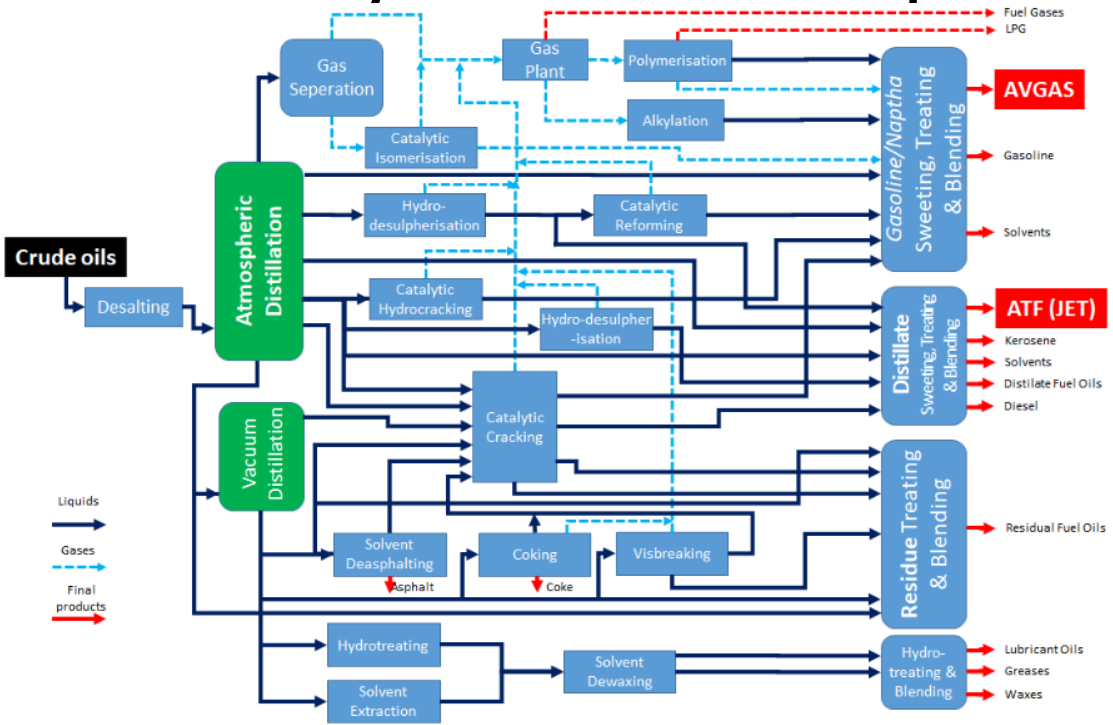
How is ATF produced and controlled



various processes must be applied to obtain the desired end products

How is ATF produced and controlled

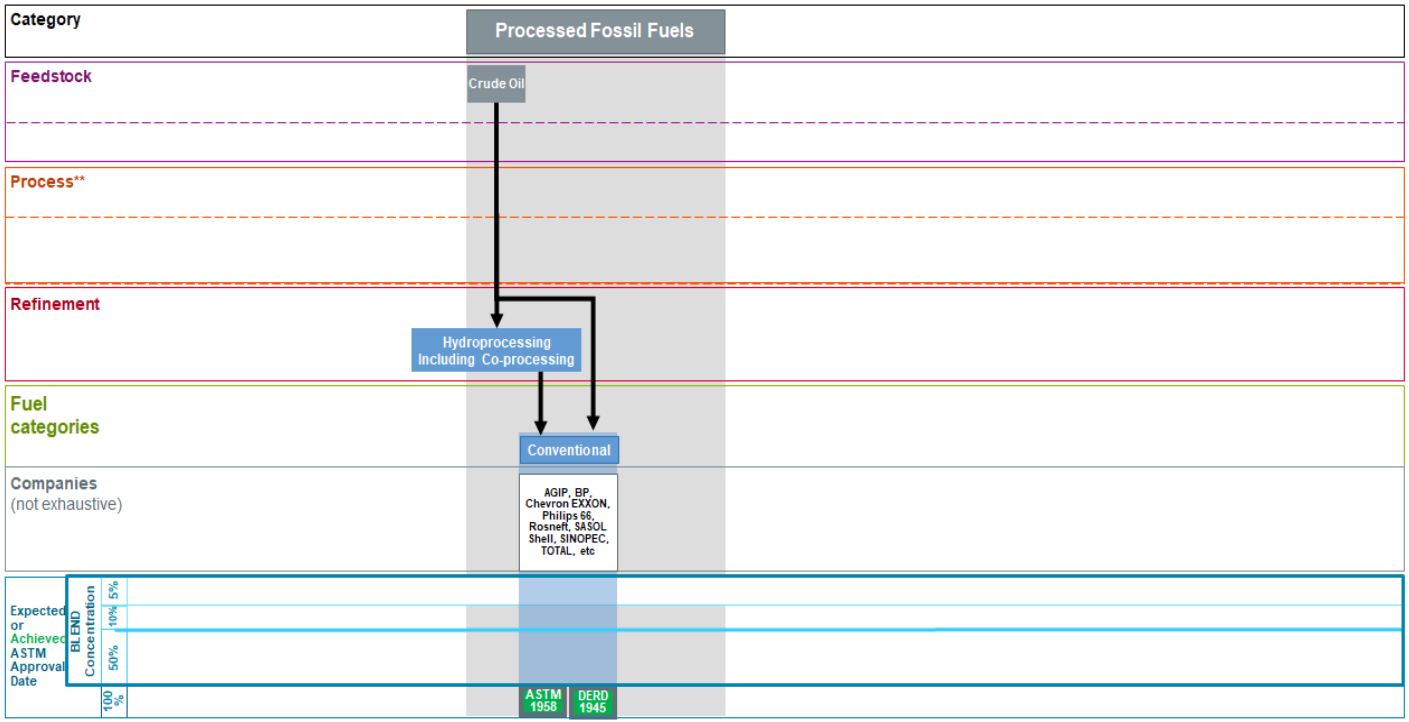
ATF is produced from various different feedstocks and transformed by numerous chemical processes.



(Example of what refinery processes look like)

How is ATF produced and controlled

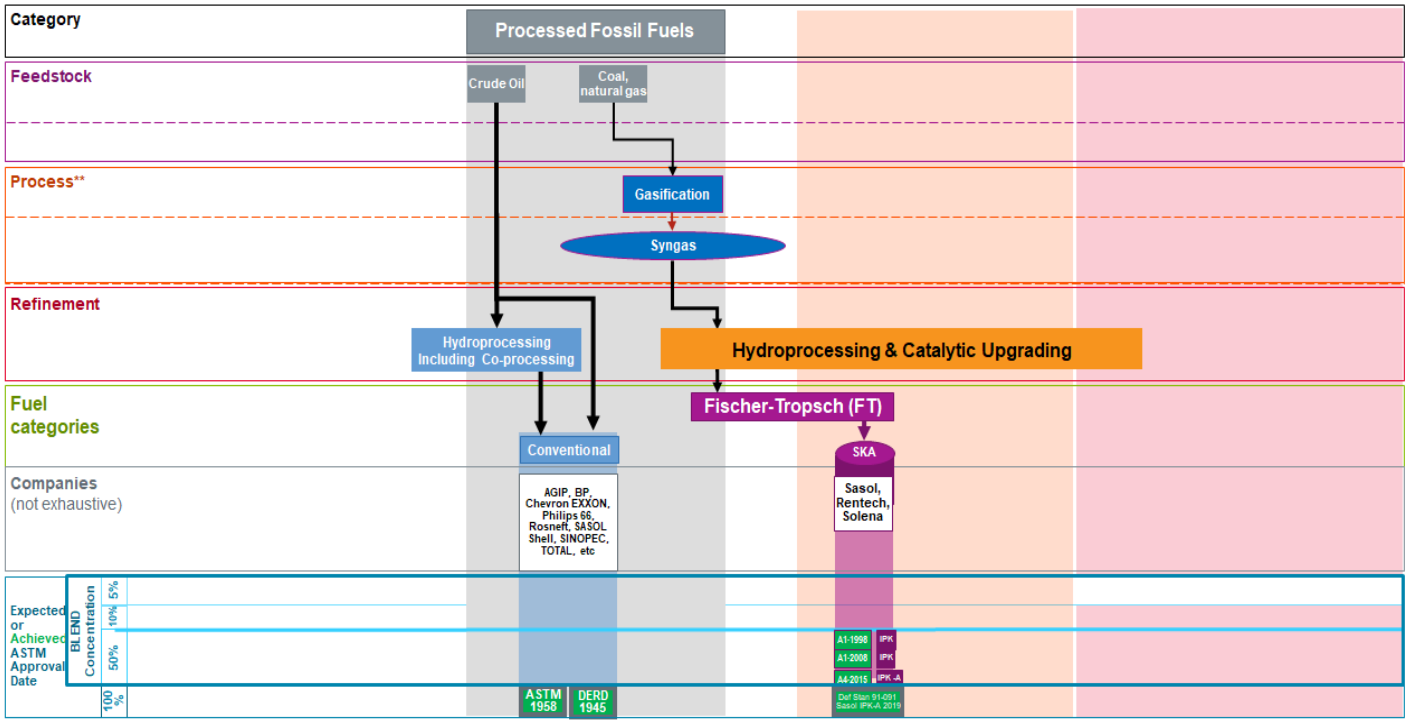
Aviation Fuel Production Pathways (1945 to 1999)



For over half a century the production of ATF was restricted to transforming crude oils.

How is ATF produced and controlled

Aviation Fuel Production Pathways (1999)



** Process / information is shown for diagrammatic purposes only
*** A1, A2, A3, A4, A5, A6, A7 refer to ASTM D7566 annexes

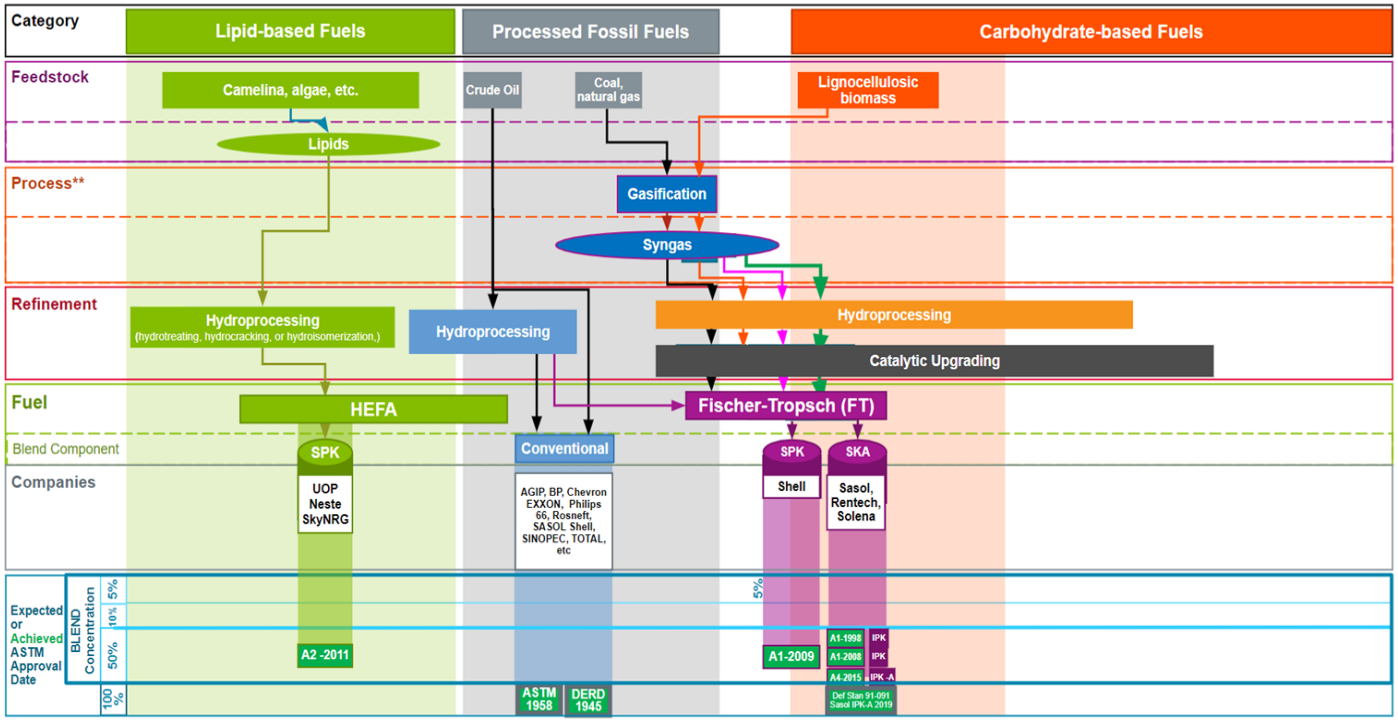
In 1999 the first non petroleum production pathway was approved

Coal was transformed using the Fischer Tropsch (FT) Process to make the first SATF known as Coal-To-Liquids (CTL).

SATF-CTL has been safely used in South Africa for over 20 years

How is ATF produced and controlled

Aviation Fuel Production Pathways (2009-2011)



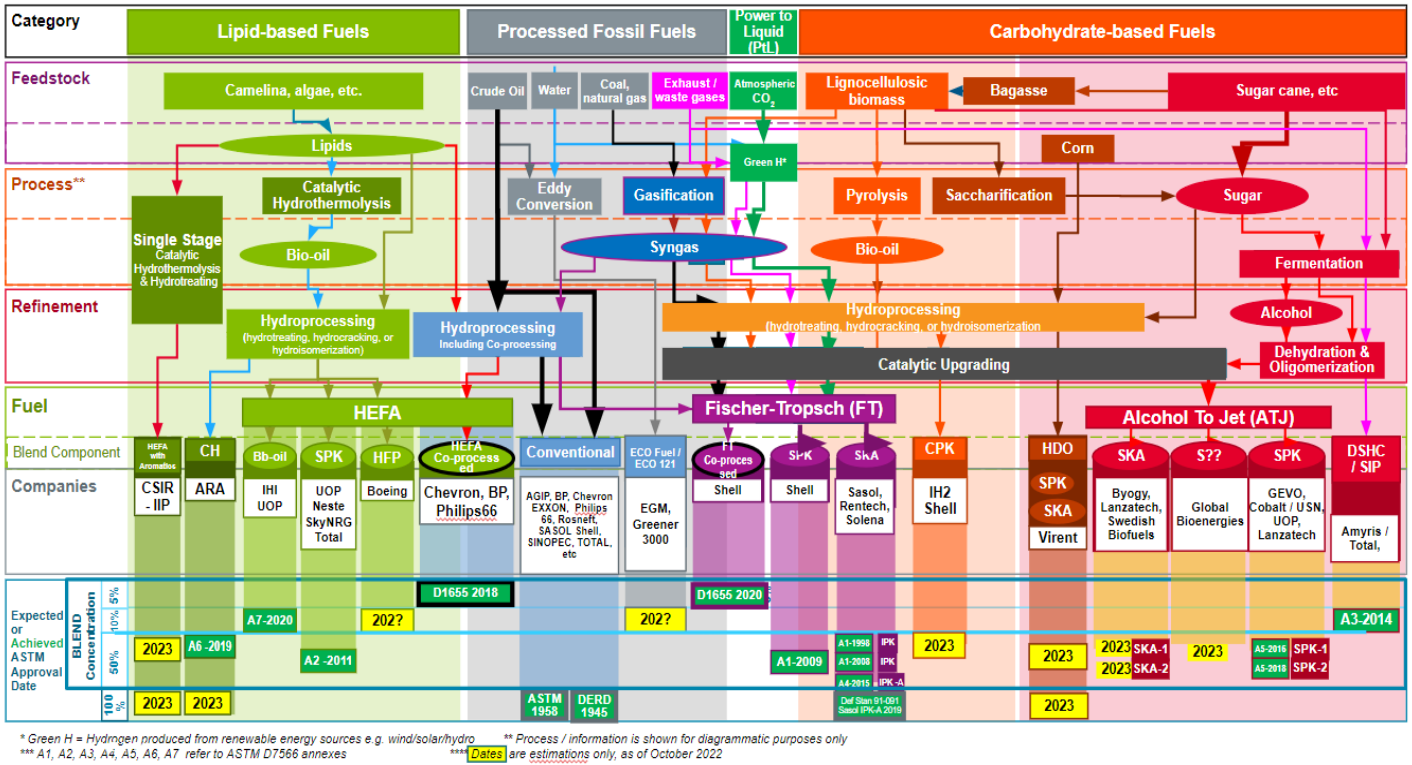
** Process / information is shown for diagrammatic purposes only
*** A1, A2, A3, A4, A5, A6, A7 refer to ASTM D7566 annexes

In 2009 the use of other non petroleum feedstocks were permitted

new fuel specification (ASTM D7566) was created to capture and control the more stringent requirements

How is ATF produced and controlled

Aviation Fuel Production Pathways



* Green H = Hydrogen produced from renewable energy sources e.g. wind/solar/hydro ** Process / information is shown for diagrammatic purposes only
*** A1, A2, A3, A4, A5, A6, A7 refer to ASTM D7566 annexes **** Dates are estimations only, as of October 2022

2023

7 conversion processes approved

+

2 distinct co-processing processes (non petroleum feedstocks co-processed with crude oil).

Approved SATF Conversion Processes

See: www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx

ASTM reference	Conversion process	Abbreviation	Possible Feedstocks	Blending ratio by volume	Commercialization proposals / Projects
ASTM D7566 Annex 1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT	Coal, natural gas, biomass	50%	Fulcrum Bioenergy, Red Rock Biofuels, SG Preston, Kaidi, Sasol, Shell, Syntroleum
ASTM D7566 Annex 2	Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids	HEFA	Bio-oils, animal fat, recycled oils	50%	World Energy, Honeywell UOP, Neste Oil, Dynamic Fuels, EERC
ASTM D7566 Annex 3	Synthesized iso-paraffins from hydroprocessed fermented sugars	SIP	Biomass used for sugar production	10%	Amyris, Total
ASTM D7566 Annex 4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	FT-SKA	Coal, natural gas, biomass	50%	Sasol
ASTM D7566 Annex 5	Alcohol to jet synthetic paraffinic kerosene	ATJ-SPK	Biomass from ethanol or isobutanol production	50%	Gevo, Cobalt, Honeywell UOP, Lanzatech, Swedish Biofuels, Byogy
ASTM D7566 Annex 6	Catalytic hydrothermolysis jet fuel	CHJ	Triglycerides such as soybean oil, jatropha oil, camelina oil, carinata oil, and tung oil	50%	Applied Research Associates (ARA)
ASTM D7566 Annex 7	Synthesized paraffinic kerosene from hydrocarbon-hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%	IHI Corporation
ASTM D1655 Annex A1	co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery	co-processed HEFA	Fats, oils, and greases (FOG) co-processed with petroleum	5%	
ASTM D1655 Annex A1	co-hydroprocessing of Fischer-Tropsch hydrocarbons in a conventional petroleum refinery	co-processed FT	Fischer-Tropsch hydrocarbons co-processed with petroleum	5%	Fulcrum

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5 - SATF blending requirements

Current D7566 SATF Production Concept

This IS Jet A/Jet A-1 Fuel

ASTM D1655 Conventional Aviation Turbine (Jet) Fuel

Crude Oil

Refinery

Conventional Jet Fuel (ASTM D1655)

ASTM D7566 Synthetic Aviation Turbine Fuel (SATF)

Blend

Synthetic Aviation Turbine Fuel (up to 50% renewable)

ASTM D7566 Annex Ax Synthetic Blend Component (SBC)

Renewable Feed Stocks

Conversion Process

Synthetic Blend Component (ASTM D7566)

Co-Processing Pathways

ASTM D1655 Annex A1 Co-Processing

Renewable Feed Stocks

Currently Limited to <5% of feed to refinery

Co-Processed Jet Fuel (ASTM D1655 Annex A1) (>= 95% petroleum/=<5% renewable)

ASTM D1655 Conventional Aviation Turbine (Jet) Fuel

Crude Oil

Refinery

Conventional Jet Fuel (ASTM D1655)

ASTM D7566 Synthetic Aviation Turbine Fuel (SATF)

Blend

Synthetic Aviation Turbine Fuel (ASTM D7566 & D1655) (up to 50% renewable)

ASTM D7566 Annex Ax Synthetic Blend Component (SBC)

Renewable Feed Stocks

Conversion Process

Synthetic Blend Component (ASTM D7566)

Why blending is required?

Aviation Turbine fuel (ATF)
100% petroleum
(Approved for flight)

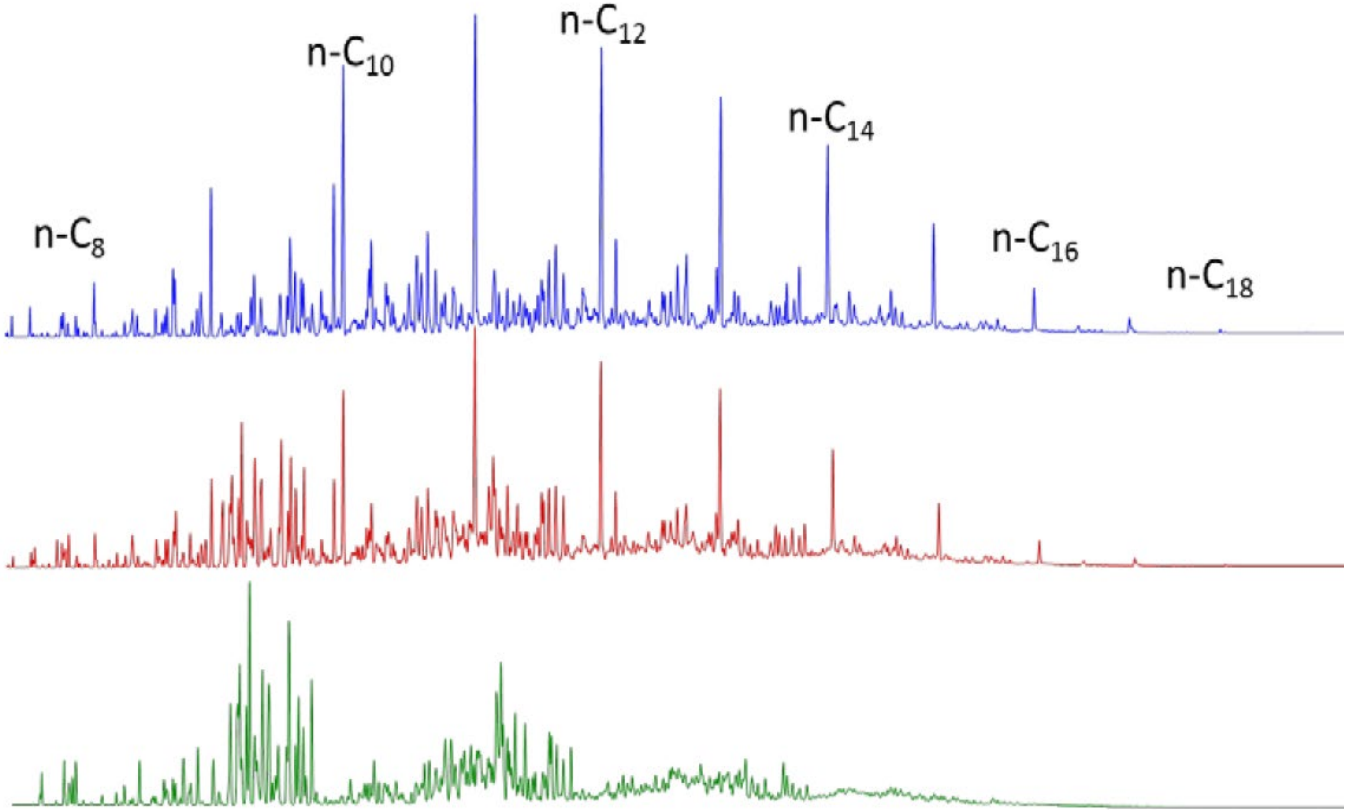
↓

SATF = ATF+SBC
(Approved for flight)

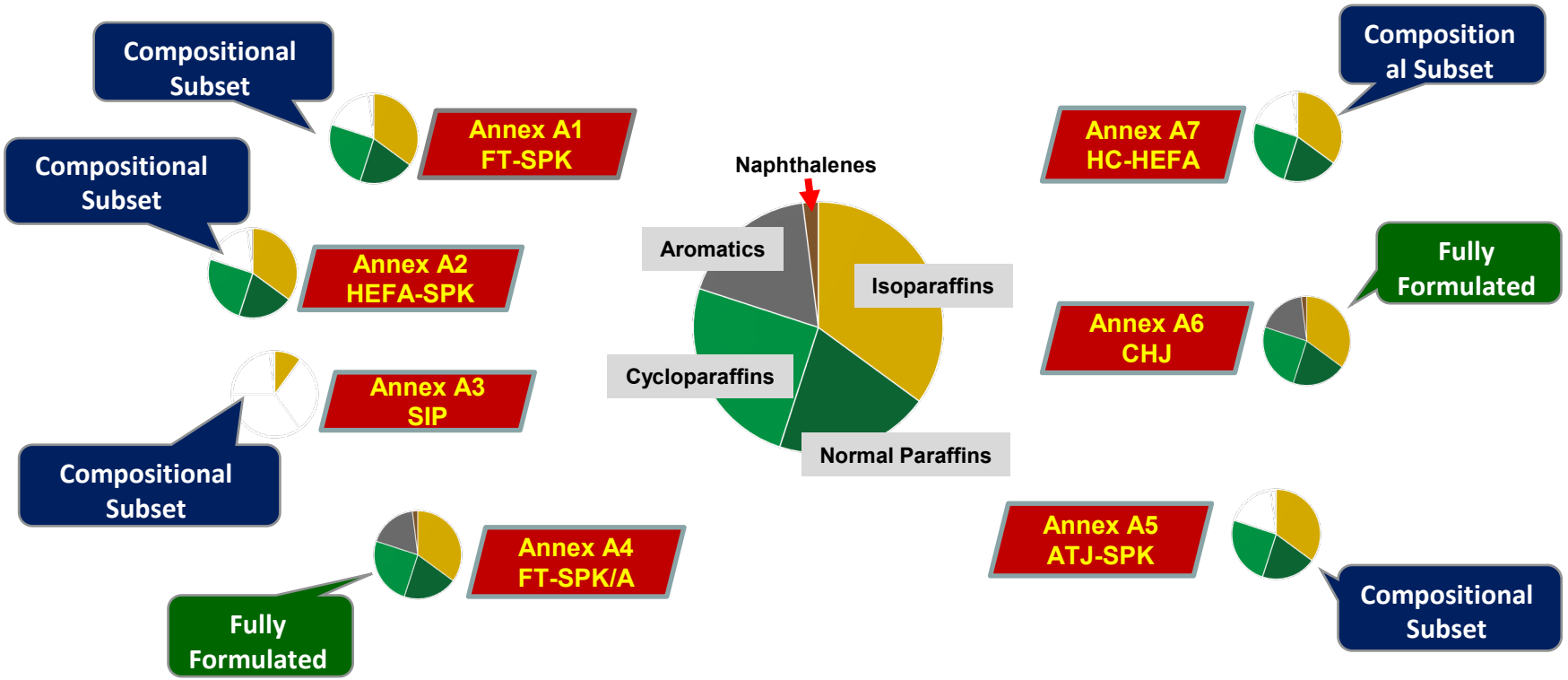
↑

100% SBC (Synthetic Blend Component)

Not approved for flight



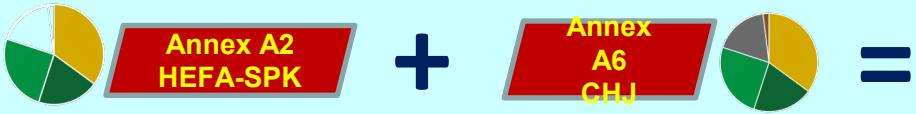
100% SATF Specification
SATF Composition Compared to Jet A Fuel



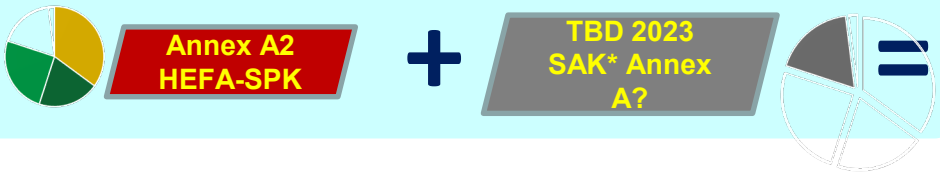
100% SATF Specification

ASTM Task Group Working on Revision to D7566 to Allow Blending of Annex Synthetic Blend Components to Allow 100% SATF

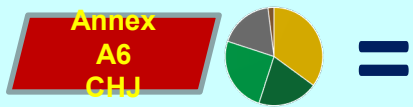
Blend A Compositional Subset Annex with a Fully Formulated Annex

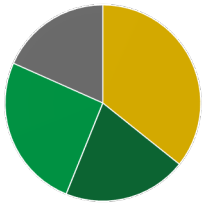


Blend A Compositional Subset Annex with a Different Compositional Subset Annex



Allow Use of a Fully Formulated Annex Without Blending





Fully Formulated SATF (a Jet A or Jet A-1 Fuel)

*SAK: Synthetic Aromatics Kerosene

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6. Overview of the Aviation Industry Process for Assessing, Controlling & Approving new Feedstocks & Processes for ATF Production

Airworthiness Authority Approval of Aviation Fuel

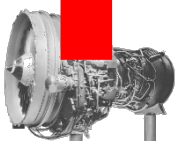
The Airworthiness Authority does not certify fuel, they certify airplanes and engines to operate on specified fuel

Jet A/A-1

- DEF STAN 91-091
- ASTM D1655
- OEM Specifications
- MIL-DTL 83133

Fuel Specification

This Must Control the Fuel Composition and Properties to Ensure a Consistent Product



Engine Ratings and Operating Limitations

Powerplant Limitations

- Fuel Specification

Operating Limitations

- Powerplant limitations in Airplane Flight Manual

Fuel is Evaluated During Aircraft and Engine Certification

Aircraft Flight Manual

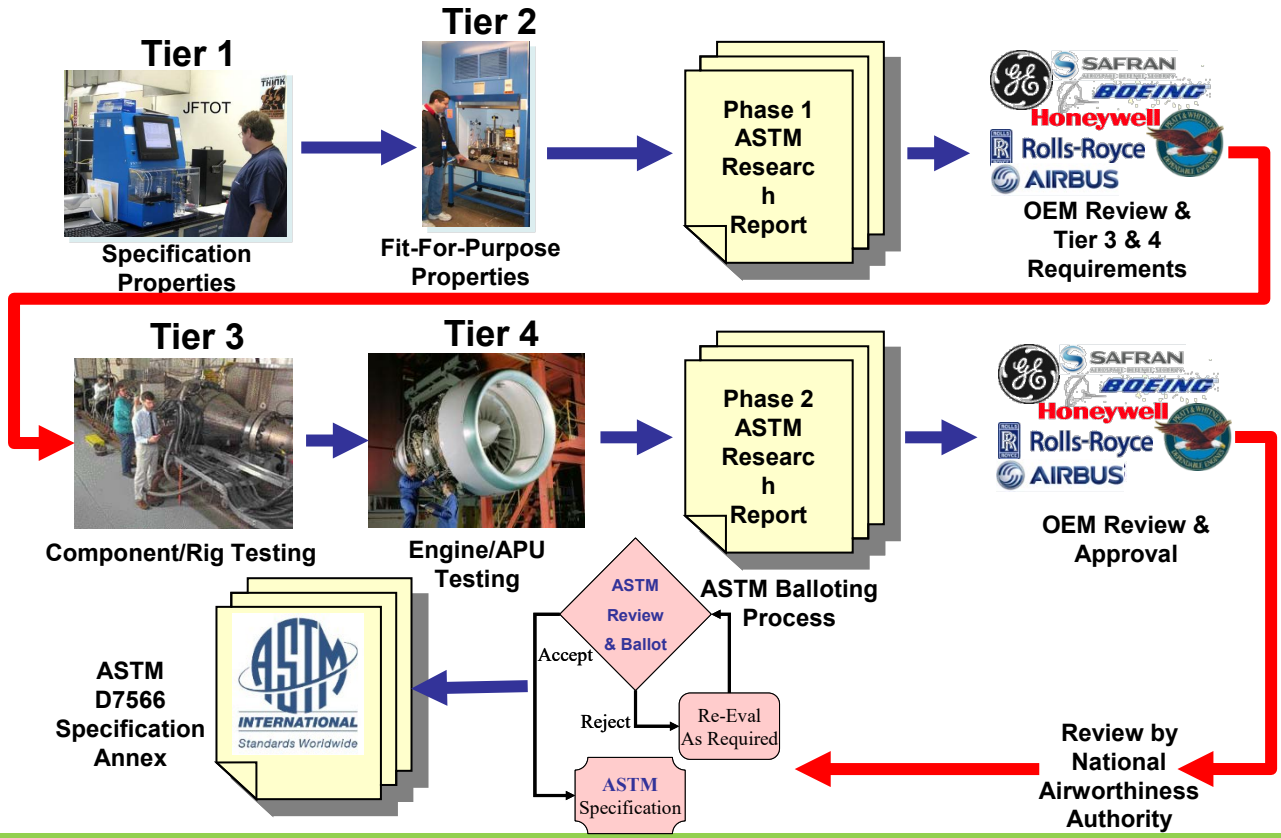
- no person may operate a civil aircraft without complying with the operating limitations specified in the approved AFM

Airlines May Only Use the Fuel Specified by the OEM

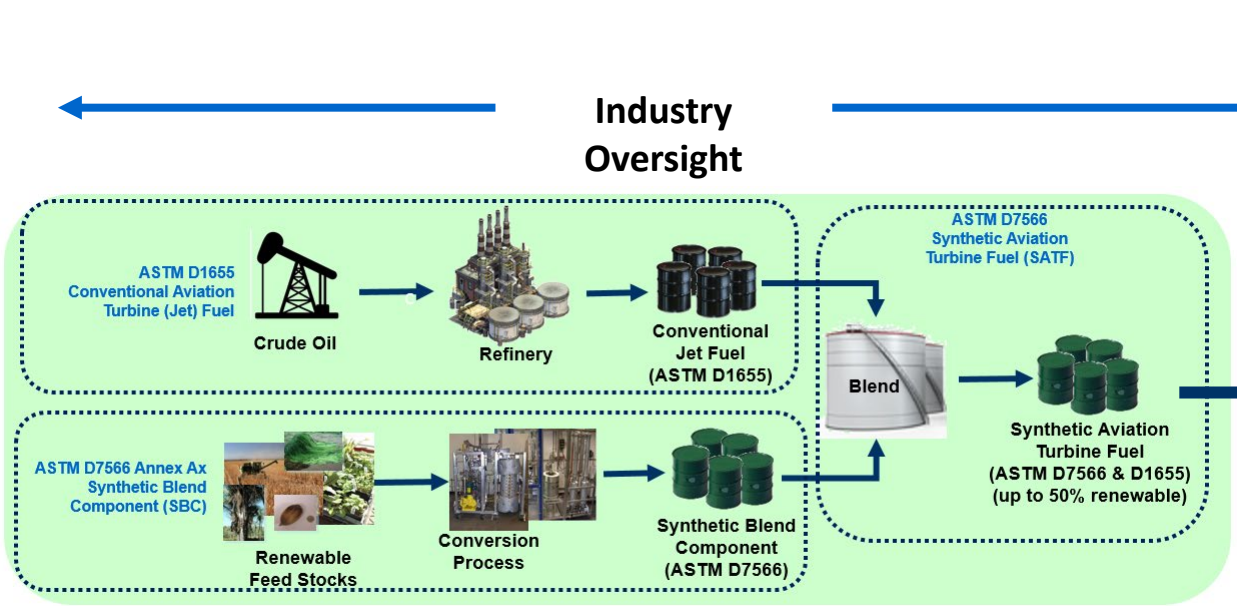
Here is Where the Airworthiness Authorities Apply Regulatory Oversight in Operations

SATF Approval

ASTM D4054 Evaluation Process



New SATF Producer Guidance



There is no requirement from the Airworthiness Authority Certification to produce SATF. However:

- An Airline customer may require "due diligence" testing after consulting with their aircraft and engine manufacturers
- The SATF producer may need to obtain sustainability certification, which do not include flight safety aspects covered by ASTM.

Airworthiness Authority Oversight

There is no requirement for an Airline to Obtain Approval from their Airworthiness Authority

- SATF is Jet A or Jet A-1 Fuel and is already approved

Conclusions

- SAF can be produced by various conversion processes today.
- Rigorous certification process ensure that SAF is safe to use in existing aircraft, when blended with conventional fuels
- Work is ongoing to allow flights with the use of 100% SAF

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